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Pre-season run size forecasts for Fraser River Sockeye salmon (*Oncorhynchus nerka*) in 2012

Prévisions pré-saison des remontes du saumon rouge du fleuve Fraser (*Oncorhynchus nerka*) en 2012

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ABSTRACT

Salmon forecasts remain highly uncertain, in large part due to the wide variability in annual salmon survival rates. For Fraser Sockeye in particular, quantitative or qualitative leading indicators of survival explored to date have not reduced forecast uncertainty and remain an active area of research. In the absence of leading survival indicators, Fraser Sockeye forecasts have been particularly uncertain in recent years, due to the systematic declines in productivity exhibited by most stocks, which culminated in the lowest productivity on record in the 2005 brood year (2009 four year old and 2010 five year old returns). Subsequently, productivity appears to have improved in the 2006 (2010 four year old returns) and 2007 (2011 four year old returns) brood years. A single forecast scenario is presented in 2012. Forecasts were produced using either recent productivity or long-term productivity (full time series) models, which were selected on a stock-specific basis based on their ability to predict true returns over the full stock-recruitment time series. Jackknife, rather than retrospective analysis, was used to generate a time series of forecasts for the model evaluation process, and a revised set of criteria and procedures were used in the model selection process. An additional sensitivity analysis was conducted to examine model performance over the most recent period of data (brood years 1997-2004), which for most stocks exhibited lower productivity. To capture inter-annual random (stochastic) variability in Fraser Sockeye survival, forecasts are presented as standardized cumulative probabilities (10%, 25%, 50%, 75%, and 90%). The 2012 forecast indicates a one in ten chance (10% probability) the total Fraser Sockeye return will be at or below 750,000, and a nine in ten chance (90% probability) it will be at or below 6.6 million, assuming survival is similar to past observations. The mid-point of this distribution (50% probability) is 2.1 million (there exists a one in two chance the return will be above or below this value). Summer Run stocks, particularly Chilko, Late Stuart and Stellako, contribute 67% to the total return forecast, whereas Early Stuart (5%), Early Summer (17%) and Late Run stocks (11%) each contribute considerably less. The forecasted 2012 Fraser Sockeye return falls largely (up to a three in four chance, based on past observations) below the cycle average (3.8 million). This below average return forecast is attributed to the well below average 2008 brood year escapements of the Early Summer and Late Run stocks. If Fraser Sockeye productivity returns to the low trend of recent decades, the 2012 return has the potential to be amongst the lowest observed on this cycle. Conversely, there is a small chance (one out of four) that returns will be above the cycle average if stock productivities fall at the high end of past observations. Due to low escapements in 2008 (which produce four year olds in 2012) relative to 2007 (which produce five year olds in 2012), the forecasted proportion of total four year old returns (~75%) is below average (82% average four year old proportion for all stocks combined, excluding Harrison). Four year old proportions ranged from 10% to 98%, depending on the stock.

RÉSUMÉ

Les prévisions pour le saumon demeurent hautement incertaines principalement en raison de la grande variation des taux de survie annuels. Dans le cas du saumon rouge du fleuve Fraser surtout, les indicateurs préalables de survie examinés jusqu'à aujourd'hui, quantitatifs ou qualitatifs, n'ont pas dissipé l'incertitude des prévisions et demeurent un secteur de recherche actif. En l'absence d'indicateurs préalables du taux de survie, les prévisions pour le saumon rouge du fleuve Fraser ont été marquées d'une incertitude particulière au cours des dernières années en raison de la baisse systématique de la productivité de la plupart des stocks. À l'année d'éclosion 2005, nous avons connu la plus faible productivité de toute l'histoire (montaisons des saumons de quatre ans en 2009 et de cinq ans en 2010). Par la suite, la productivité semble s'être améliorée au cours des années d'éclosion 2006 (montaisons des saumons de quatre ans en 2010) et 2007 (montaisons des saumons de quatre ans en 2011). Seul un scénario prévisionnel est présenté en 2012. Les prévisions ont été générées à l'aide de modèles de productivité récente ou à long terme (modèles complets des séries chronologiques), sélectionnés en fonction des stocks d'après leur capacité à prévoir plus justement la réalité des stocks que les modèles complets de stock et de recrutement des séries chronologiques. Pour l'évaluation du modèle, on a eu recours à une analyse jackknife plutôt qu'à une analyse rétrospective pour générer une série chronologique de prévisions, et pour le processus de sélection du modèle, on a utilisé un ensemble de critères et de procédures révisés. Une nouvelle analyse de la sensibilité a été menée afin d'évaluer le rendement du modèle pour la période de données la plus récente (années d'éclosion 1997 à 2004), qui a affiché une baisse de la productivité pour la plupart des stocks. Pour consigner la variabilité aléatoire (stochastique) interannuelle des taux de survie du saumon rouge du fleuve Fraser, les prévisions sont présentées sous forme de probabilités cumulatives normalisées (10 %, 25 %, 50 %, 75 % et 90 %). Les prévisions de 2012 indiquent qu'il y a une chance sur dix (probabilité de 10 %) que la montaison totale du saumon rouge du fleuve Fraser soit de 750 000 individus ou moins, et qu'il y a neuf chances sur dix (probabilité de 90 %) qu'elle soit de 6,6 millions d'individus ou moins, si l'on suppose que le taux de survie ressemble à celui des observations antérieures. La valeur médiane de cette répartition (probabilité de 50 %) est de 2,1 millions d'individus (il y a une chance sur deux que les montaisons soient supérieures ou inférieures à cette valeur). Les stocks de montaison d'été, surtout dans le cas des montaisons de la Chilko et de la Stellako ainsi que de la montaison tardive de la Stuart, constitueront 67 % des prévisions de montaisons totales. Toutefois, les montaisons hâtives de la Stuart (5 %) et d'été (17 %) ainsi que les stocks de montaison tardive (11 %) y contribueront considérablement moins. Les prévisions de la montaison du saumon rouge du fleuve Fraser pour 2012 se situent principalement (jusqu'à trois chances sur quatre, selon les observations antérieures) sous la moyenne du cycle (3,8 millions). On attribue ces prévisions d'une montaison inférieure à la moyenne aux échappées nettement sous la moyenne des stocks de la montaison hâtive d'été et de la montaison tardive au cours de l'année d'éclosion 2008. Si la productivité du saumon rouge du fleuve Fraser tend à redevenir faible telle qu'elle l'était lors des dernières décennies, la montaison de 2012 risque d'être l'une des plus faibles observées pour ce cycle. Par contre, il existe une faible possibilité (une chance sur quatre) que les montaisons soient supérieures à la moyenne du cycle si les productivités des stocks sont dans la fourchette supérieure des observations antérieures. En raison des échappées de 2008 (qui a produit les saumons de quatre ans en 2012), faibles par rapport à celles de 2007 (qui a produit les saumons de cinq ans en 2012), la proportion de saumons de quatre ans du total prévu de montaison (~75 %) est inférieure à la moyenne (82 % de la proportion de saumons de quatre ans pour tous les stocks combinés, sauf pour la montaison de la Harrison). Les proportions prévues de saumons de quatre ans varient de 10 % à 98 % selon les stocks.

1 INTRODUCTION

1.1 OVERVIEW

Pre-season return forecasts are produced annually for 19 Fraser Sockeye stocks and six additional miscellaneous stock groups using a suite of forecast models. Most forecast models use brood year spawner abundances or juvenile data to predict returns, though some models predict future returns using exclusively past return data. Given that there are a number of both non-parametric and biological model forms that can be used to generate a stock's annual forecast, model performance is evaluated for each stock using jack-knife analysis and a suite of performance measures. Each performance measure ranks models against one another according to how well (how precise and/or accurate) they predict true returns. For each stock, these rankings are used in combination with a model selection process (described in the proceeding Methods section) to select the model used to generate the 2012 forecast.

The overall 2012 Fraser Sockeye forecast approach is adapted from methods described in previous forecasts (Cass et al. 2006; DFO 2006; DFO 2007; DFO 2009; Grant et al. 2010; DFO 2012; Grant and MacDonald 2012). However, the following key changes were made in 2012:

1) a single forecast scenario is presented;

2) the full suite of applicable candidate models (recent and long-term productivity models) was evaluated for each stock (Table 4);

3) jackknife (leave-one-out) cross-validation (CV) analysis was used to generate the historical forecast time series' for the model evaluation process;

4) the model selection process and criteria, used to select the 2012 forecast model for each stock, were revised;

5) an additional sensitivity analysis was conducted to examine model performance over only the more recent period of productivity (Appendix 1).

The 2012 forecast scenario evaluates all applicable models (those that consider long-term productivity and recent productivity) for each stock using all available stock-recruitment data (typically brood years 1948-2004). Miscellaneous stocks, for which recruitment data are unavailable, were forecast using the product of their brood year escapements and the long-term (full stock-recruitment time series) average productivity of spatially and temporally similar stocks with stock recruitment data (index stocks), as identified in Table 1 (footnotes e, f, g, h, i, l). Assumptions about future productivity are not explicitly presented as separate scenarios, as they were in the 2010 and 2011 forecasts. For those previous forecasts, recent productivity models were evaluated only for the recent (generally low) productivity period ('Recent Productivity' scenario), and long-term productivity models were evaluated across the full time series ('Long-Term Productivity' scenario).

Cross-validation (CV) refers to a general method of evaluating the predictive ability of a model, and is commonly used for model selection (Arlot and Celisse 2010). Using CV, the available data are split into a '**calibration sample**' (data used to fit the model), and a separate '**validation sample**' (data used to test the model). These data sets are independent, therefore the method avoids overly optimistic evaluations of model performance that result from model overfitting (Arlot and Celisse 2010). The Fraser Sockeye forecast process has historically relied on retrospective analysis, a type of CV (Shao 1993), for model evaluation (Cass et al. 2006; DFO 2006; DFO 2007; DFO 2009; Grant et al. 2010; DFO 2012; Grant and MacDonald 2012). For the 2012 forecast, an alternative method of CV, known as jack-knife (or leave-one-out)

analysis, was employed. Both the retrospective and jackknife methods are used to generate a time series of forecasts, which are then compared to actual returns to evaluate each model's accuracy and/or precision in forecasting (calculated with performance measures).

Jack-knife analysis involves an iterative process of moving through a time-series of data, sequentially removing one year of data (used for model validation), and using the remaining time-series to fit a model (used for model calibration), which is subsequently used to predict the missing year of data (Refaeilzadeh et el. 2009). This approach differs from the previously used retrospective method in that jack-knife analysis generates a return forecast for every year in the entire stock-recruitment time-series (typically 1948-2004), whereas retrospective analysis generates forecasts for only the second half of the time-series (typically 1976-2004). Therefore, the number of validation samples used in the jackknife approach is double that of the retrospective approach. In addition, the size of the calibration sample (the stock-recruitment data used to seed models) is largely stationary in jackknife analysis and, in contrast, changes over time when using retrospective analysis. Specifically, since the retrospective CV approach uses only stock-recruitment data prior to the forecast year to produce each annual forecast (starting with the first year in the second half of the time series), the calibration sample sequentially increases in size for each subsequent validation sample, starting at half the size of the jackknife sample (full stock-recruitment time series minus the forecast year) and ending equal in size to the jackknife sample. Smaller sample sizes have resulted in underestimates of model performance (Steyerberg et al. 2001) and can also produce poor assessments of prediction accuracy (McCuen 2005; Steyerberg et al. 2001). Therefore, when using retrospective analysis, since calibration sample sizes for the early validation years are small relative to later years, model performance evaluations may be confounded by changes in the calibration sample size. Further, since the calibration samples used in retrospective analysis are largely comprised of the first half of the time series, the characteristics of the calibration sample may vary from the validation sample (McCuen 2005). Since most Fraser Sockeye stocks have exhibited systematic declines in productivity starting as early as the 1950's, characteristics of the calibration sample would be weighted more on the earlier, more productive, half of the time series, compared to the validation sample, which would be weighted more on the later, less productive half of the time series.

Jackknife analyses exclude only the year of data being evaluated when generating each forecast, therefore, this type of analysis is not as sensitive to the issues of sample size (McCuen 2005) as retrospective analysis. In addition, since jack-knife analysis uses all of the available data (except for one year) to fit models in every year of the validation time series, the characteristics of the calibration sample will be similar to the validation sample. Moreover, the jackknife model calibration samples will be near-identical to those used with each model form to generate the 2012 forecast. The jack-knife approach was therefore adopted in 2012 as a more appropriate method of model evaluation, since it better reflects the predictive models used in 2012, and it avoids the issues associated with both small sample size, and diverging characteristics between the calibration and validation samples.

Jackknife analysis results for the 2012 forecast were used in combination with actual return data to calculate performance measures for the evaluation of relative model performance. Similar to previous forecasts, top model selection is based on average model performance across the four performance measures. However, in contrast to previous year's forecasts, an additional step was added in 2012 in which model performance was evaluated separately for each of the four performance measures (see subsequent Methods section). In 2012, a final model selection procedure and set of criteria were used to select a single forecast model for each stock, similar to previous years forecasts.

An additional sensitivity analysis was conducted in the 2012 forecast process. For this analysis model performance was evaluated over a truncated time series (1997-2004 brood years) by stock (Appendix 1). The sensitivity analysis compares model performance over the recent,

generally low productivity period, rather than over the full range of productivities observed over the entire time series. All other methods used to select the final forecast for the sensitivity analysis were identical to the 2012 forecast. Miscellaneous stocks, for which recruitment data is unavailable, were forecast using the product of their brood year escapements and the average recent (brood years 1997-2004) productivity for spatially and temporally similar stocks with stock recruitment data (index stocks), as identified in Table 1 (footnotes e, f, g, h, i, l).

1.2 HISTORICAL ADULT RETURNS

Fraser Sockeye return abundances have historically varied, due to the four-year pattern of Sockeye abundance (cyclic dominance) observed for many stocks, and variability in annual survival rates (see Figure 5 in Grant et al. 2011). In recent years in particular, Fraser Sockeye have exhibited extremely large variations in returns, ranging from one of the lowest returns (2009 return year) to one of the highest returns (2010 return year) observed over the past century (see Figure 5 in Grant et al. 2011).

To provide context for the 2012 forecasts, the average returns of Fraser Sockeye on the 2012 cycle are presented in Table 1 (column I). The 2012 cycle has the lowest average return of the four cycles of Fraser River Sockeye, with an average annual Fraser Sockeye return (1956-2008) of 3.85 million for all 19 forecasted stocks combined. Chilko (Summer Run) has historically been the main driver of returns on this cycle line, accounting for 47% of the average total. Stellako, Weaver and Birkenhead have also contributed relatively high proportions to the cycle average, at 12%, 9% and 7% respectively. Stocks that have each comprised greater than 2% of the average return on the 2012 cycle include Early Stuart, Gates, Nadina, Pitt and Late Stuart. All remaining stocks contributed less than 2% to the cycle average return.

1.3 ESCAPEMENT IN THE 2007 AND 2008 BROOD YEARS

The abundance of adult returns in any given year is influenced by three main factors: the abundance of their parental spawners (brood year escapement as an index of egg deposition), the survival rate of the resulting offspring (egg to adult stages), and the age composition of each cohort that survives to adulthood. Since most Fraser Sockeye return as four year old fish after spending two winters in freshwater and two winters in the marine environment (Gilbert-Rich aging convention: 4_2), the majority of Sockeye returning in 2012 are recruited from eggs spawned by adults in 2008 (brood year). Most of these returning fish would have emerged from the gravel in 2009, and migrated to the ocean in 2010.

Overall, the number of effective females spawners (EFS) in the 2008 brood year (274,000 EFS) was the lowest on the 2012 cycle since 1968. For most stocks returning in 2012 (13 out of 19), brood year effective female spawner (EFS) or smolt (Chilko and Cultus) abundances were well below their time-series cycle average (1948-2004 for most stocks), including Bowron, Fennell, Gates, Pitt, Scotch, Seymour, Chilko, Cultus, Late Shuswap, Birkenhead, Portage, Harrison and Weaver (Table 1, column C). These brood year escapements, in most cases, were the lowest or amongst the lowest on record for these stocks. For the remaining 6 out of 19 stocks, brood year EFS abundances were close to, or above, their time series cycle average (1948-2004 for most stocks), including Early Stuart, Nadina, Raft, Late Stuart, Quesnel and Stellako (Table 1, column C). Three Summer Run stocks (Stellako, Chilko and Late Stuart) contributed the greatest overall proportion (71%: ~ 24% each) to the total 2008 brood year EFS. The Chilliwack Lake/Dolly Varden Creek miscellaneous stock, Early Stuart and Nadina contributed, on average, 4% each to the total EFS. All remaining stocks contributed less than 2% to the total EFS. Cultus Sockeye have high hatchery contributions in the fry to smolt stage that make EFS comparisons inappropriate

Most Fraser Sockeye stocks also have a five year old (5_2) component that contributes, on average, 20% to their total recruitment. For approximately half of the forecasted Fraser Sockeye stocks (Early Stuart, Bowron, Gates, Nadina, Seymour, Stellako, Late Shuswap, Cultus and

Portage), 2007 brood year EFS abundances (contributing to five year old returns in 2012) were below their cycle average (most time series: 1951-2003). For the other half of these stocks (Fennell, Pitt, Raft, Scotch, Chilko, Late Stuart, Quesnel, Weaver and Birkenhead), 2007 brood year EFS abundances were above, or close to, their cycle average. Given this pattern in escapements for the 2008 and 2007 brood years, the five year old component may contribute more than 20% to the total return in 2012. Pitt returns are typically comprised of a larger proportion of five year old Sockeye relative to four year old Sockeye, therefore, the 2007 brood year, which was above average, will contribute more to the total returns than the 2008 brood year. Harrison has an age-3 (3_1) component, which contributes variable proportions to the total Harrison recruitment. The brood year EFS abundance for Harrison in 2009 was above average.

1.4 SURVIVAL RATES (PRODUCTIVITY)

In recent decades, productivity across all Fraser Sockeye stocks has generally declined (Figure 1), though individual trends vary amongst stocks (Grant et al. 2010; Grant et al. 2011; Peterman and Dorner 2011). Systematic declines in total productivity have coincided with declines in marine survival, as opposed to freshwater survival, based on survival trends observed in the Chilko indicator stock (Figure 2). One notable exception is Harrison Sockeye, which have increased in productivity in recent years (Grant et al. 2010; Grant et al. 2011). Harrison Sockeye have a unique age-structure and life-history compared to all other stocks. This stock migrates to the ocean shortly after gravel emergence (most other Sockeye rear in lakes for one to two years prior to ocean migration) and returns as three and four year old fish (most other Sockeye return as four and five year olds).

For most Fraser Sockeye stocks, declining productivity trends culminated in amongst the lowest productivity on record (Figure 1 and Figure 2 B) in the 2005 brood year, including Harrison (which has increased in productivity in recent years). Subsequently, the 2006 brood year (2010 return year for most of these Sockeye) and 2007 brood year (2011 return year for most of these Sockeye) had average to above average productivity for most stocks. In the absence of leading survival indicators, it is unclear whether these recent improvements in productivity will persist long-term.

2 METHODS

2.1 DATA

2.1.1 Biological Data

Annual estimates of Sockeye spawning escapement, fry or smolt abundance (if and when available), and recruits (sum of catch, escapement, and en-route loss) by stock are the primary data used to forecast Fraser Sockeye returns for the 19 forecasted stocks. For miscellaneous stocks, only escapement data are available. Escapement data used in the forecast are in the form of effective female spawners (EFS): the product of female spawners and the proportion of successfully spawned eggs (0%, 50%, or 100%), based on spawning ground carcass surveys. For most stocks with spawner and recruitment data, the time series by brood year extends from 1948 to 2004 (1952-2008 return year), with the following exceptions: Fennell (1967-2004), Gates (1968-2004), Nadina (1973-2004), Scotch (1980-2004), Portage (1953 to 2004) and Weaver (1966-2004). For these stocks, earlier data were omitted due to gaps in the time series (Fennell, Scotch, Portage) or because of the effect of spawning channels, which began operation in the late 1960's (Gates, Weaver) or late 1970's (Nadina). The last brood year for which full recruitment data (four and five year olds) are available is 2004. Final five year old recruitment data by stock from the 2005 brood year (returned in 2010), and four and five year old recruitment from the 2006 brood year (returned in, respectively, 2010 and 2011) were not

finalized at the time of publication. Processing of 2010 age-at-return data was not completed by the Pacific Salmon Commission (PSC) until late November 2011, due to an ongoing review of the return calculation process (M. Lapointe, PSC, pers. comm.). The 2005 brood year data (which includes escapements and preliminary data on four year old recruits in 2009) were used only in the four year old productivity time-series presented in Tables 1 and 2. Four year old productivity is the four year old recruitment divided by the brood year EFS (i.e. for the 2005 brood year, the four year old returns in 2009 are divided by the EFS in 2005).

Forecasts using juvenile data were included in the evaluation for the following four stocks: Chilko (smolt), Cultus (smolt), Weaver (fry), and Nadina (fry). Gates (fry) and Early Stuart (fry) juvenile data were not used in the forecast process, as juvenile estimates for these stocks represent highly uncertain indices of abundance only. Quesnel (fall fry) and Late Shuswap (fall fry) juvenile data were also not used in the 2012 forecast process, because field surveys were not conducted to estimate fry production from the 2008 brood year. For Cultus, smolt data were used as the sole predictor variable in biological models, as Cultus Sockeye have been enhanced (fry and smolts) through hatchery production since the 2000 brood year. Cultus smolt data includes the total number of smolts (wild + hatchery produced smolts are included post-2000) migrating through the Sweltzer Creek enumeration fence, plus (post-2000 brood year) hatchery produced smolts released downstream of the fence. The Cultus smolt time-series is intermittent, and begins in 1950. Fry data for Weaver (brood years 1968-present) and Nadina (brood years 1972-present) include production from both within and outside the spawning channels. In recent years when fry assessments were not conducted outside the channels, non-channel fry were estimated by multiplying the brood year EFS by the historical average fry-per-EFS in each of these systems.

As an overview of the biological data inputs used by the forecast models, brood year EFS (or smolt) and age-4 productivity ($\log_e$(age-4 R/EFS) or $\log_e$(age-4 R/smolt)) are presented relative to their cycle averages in Tables 1 and 2. Red, green or yellow were used to represent whether these data were below, above, or near their cycle averages, respectively. The cycle average and standard deviation of each EFS time-series (brood years 1948-2004) were used to set the upper and lower bounds that delineate these three zones (below average, above average, or near average). Specifically, the time-series cycle average minus half the cycle standard deviation was used to set the lower bound (any value falling below this lower bound is coded red: below average), and the time series cycle average plus half the cycle standard deviation was used to set the upper bound (any value falling above this upper bound is coded green: above average) (Trudel, M., DFO pers. comm.). Values falling within the upper and lower bounds are coded yellow: average. For Harrison, due to the large standard deviation in the EFS time-series (Harrison escapements have increased considerably in recent years), the lower and upper bounds were set using one quarter of the standard deviation. A similar colour-coding is used for the forecasted returns and for four year old productivity. However, for four year old productivity the data were log-transformed, and geometric means for the most recent four and eight year periods were colour-coded with reference to the geometric average and standard deviation for 1980-2005 (across all cycles). Again, four year old data from the 2005 brood year (four year old recruits in 2009) were used in the four year old productivity time-series

Escapement and wild smolt (Cultus and Chilko) data were provided by DFO Fraser Stock Assessment (DFO, Keri.Benner@dfo-mpo.gc.ca), channel fry data (Nadina and Weaver) were provided by DFO Oceans, Habitat and Enhancement Branch (DFO, Roberta.Cook@dfo-mpo.gc.ca), data for Cultus hatchery smolt numbers (released downstream of the Sweltzer Creek enumeration fence) were obtained by DFO Oceans, Habitat and Enhancement Branch (Stuart.Barnetson@dfo-mpo.gc.ca), and recruitment data were provided by the Pacific Salmon Commission (PSC) (Lapointe@psc.org).

2.1.2 Environmental Data

In additional to biological data, several biological models incorporate environmental data, listed below:

1. Pacific Decadal Oscillation (PDO): winter PDO (November to March months, inclusive, immediately prior to smolt outmigration) was used as a broad index of sea surface temperature (SST) in the North Pacific (Mantua et al. 1997); http://jisao.washington.edu/pdo/PDO.latest

2. Sea-Surface-Temperature (SST): SST data from two lighthouses were used, as these sites are thought to best represent conditions experienced by juvenile Fraser Sockeye during their initial stages of migration in the marine environment. The two lighthouse locations are Entrance Island (Strait of Georgia, proximate to Nanaimo) and Pine Island (NE corner of Vancouver Island.

> **a) Entrance Island:** average SST data (April to June) in the Strait of Georgia where juvenile Fraser Sockeye first enter the marine environment (see web link above).
>
> **b) Pine Island:** average SST data (April to July) on the northern tip of Vancouver Island (see web link above).

4. Fraser discharge (peak and average April to June mean discharge): coincides with the outmigration timing of Fraser Sockeye smolts http://www.wsc.ec.gc.ca/applications/H2O/index-eng.cfm

2.2 MODELS

2.2.1 Non-Parametric Models

Non-parametric models forecast future returns using the historical time series, and do not require parameter estimation (Table 4; see Appendix 1 in Grant et al. 2010 for details). Four non-parametric models (R1C, R2C, RAC, TSA) do not include spawner (or juvenile) abundance as a predictor variable, but instead use total return data to generate forecasts (Cass et al. 2006; Haeseker et al. 2008). An additional six non-parametric models (RS1, RS2, RS4yr, RS8yr, MRS, RSC) forecast returns using the product of spawner (or juvenile) abundance and recruits-per-spawner averaged over different time periods. Forecast distributions for non-parametric models were estimated as the residual error (forecast minus actual return) for each model determined using jack-knife re-sampling.

Miscellaneous stocks do not have associated recruitment data and, therefore, were forecast using non-parametric models only (Table 4; see Appendix 1 in Grant et al. 2010 for details). Forecasts for miscellaneous stocks were generated using use the product of their brood year EFS and the R/EFS for index stocks (stocks with paired stock-recruitment data that are in the same run timing group and occupy a similar geographic area to the miscellaneous stocks). Specifically, index stocks included Scotch and Seymour for the South Thompson miscellaneous stocks; Raft and Fennell for the North Thompson miscellaneous stocks; the aggregate Early Summer run timing stocks (eight non-miscellaneous stocks in Table 1) for the Nahatlatch and Chilliwack miscellaneous stocks; and Birkenhead for the Non-Shuswap (Harrison Lake rearing) miscellaneous stocks. Forecast distributions are estimated using the $\log_e$ mean and standard deviation of the stock-recruitment time series for associated index stocks.

2.2.2 Biological Models

Biological models (e.g., Ricker, power, or Larkin) forecast returns based on the relationship between spawners (or juveniles) and recruits, and they require parameter estimation (Table 4; see Appendix 2 in Grant et al. 2010 for details). Only stock-recruitment models include environmental variables as covariates. Bayes posterior parameter distributions for the biological

models were estimated using WinBUGS (Bayesian software Using Gibbs Sampling) (WinBUGS is available on the following website: http://www.mrc-bsu.cam.ac.uk/bugs/welcome.shtml). The R statistical software and the BRugs library were used to automate the analysis (R is available on the following website: http://www.biostat.umn.edu/~brad/software/BRugs/). In each trial, the MCMC burn-in length was set to 20,000 samples from the posterior distribution. A further 30,000 MCMC samples were taken to approximate the posterior probability distributions of the model parameters and associated forecast.

2.2.3 Return Estimation: Age Proportions

Most Fraser Sockeye stocks are comprised of four (of 4_2) and five (5_2) year old fish. Therefore, the total number of returning recruits in 2012 is the sum of the forecasted number of four year old recruits produced by spawners in the 2008 brood year, and the five year old recruits produced by spawners in the 2007 brood year (see Appendix 3 in Grant et al. 2010). In order to generate a forecast of four year old recruits, the total number of recruits (four plus five year olds) produced by spawners from the 2008 brood year was multiplied by the average stock-specific proportion of four year old recruits since 1980. Similarly, to forecast five year old recruits, the total number of recruits produced by spawners from the 2007 brood year was multiplied by the average stock-specific proportion of five year old recruits since 1980. For the cyclic Ricker model (Ricker-cyc), age proportions were calculated individually on each cycle line using post-1980 (1980-2004 brood years) recruitment age proportion data. Specifically, for 2012 four year old forecasts, four year old proportions were calculated on the four year old brood year cycle line (i.e. 2008) and for 2012 five year old forecasts, five year old proportions were calculated on the five year old brood year cycle line (i.e. 2007).

Age proportions for all stocks (generally the proportion of four year olds to five year olds) were estimated using a truncated period of spawner data (1980-2004), as was introduced in the 2011 Fraser Sockeye forecast (Grant and MacDonald 2012). This change was added to the methods because age at maturity has increased for most stocks post-1980 (Grant et al. 2010; Holt and Peterman 2004).

Unlike other stocks, Harrison Sockeye returns have varying proportions of three (3_1) and four (4_1) year old fish. Therefore, forecasted returns for the upcoming year (i.e. 2012) were calculated by summing the three (2009 brood year) and four year old recruitment (2008 brood year) forecasts. The proportion of Harrison recruits that return as three or four year olds is highly variable, with higher percentages of four year old fish (~65%) returning during odd years when pink salmon are also spawning in this system. Therefore, the proportion of recruits that return as three and four year old Sockeye was calculated separately for even and odd years for the Harrison stock, and the time-series was also truncated to include only years since 1980. For miscellaneous stocks, average four year old proportions were calculated from the recent stock-recruitment time series for associated index stocks.

2.3 MODEL EVALUATION

2.3.1 Jack-knife Analysis

The jack-knife CV approach, used in the first step of the model evaluation process, generates a return forecast for each year in the entire stock-recruitment time-series (typically 1948-2004). For each model, it moves through the stock-specific time-series from start to finish, removing only the four and five year old recruits for the single year being forecast, and using the remaining stock-recruitment data to fit the model. For each year it uses this model fit to produce a total 'forecasted' return as it sequentially progresses through the time-series of data.

Since age at maturity for Fraser Sockeye stocks has increased since the 1980's (with increasing proportions of four year old relative to three year old fish, and five year old relative to four year

old fish) (Grant et al. 2010; Holt and Peterman 2004), jack-knife forecasts were calculated using truncated age-proportion data to incorporate these changes. Specifically, for jack-knife forecasts prior to 1978, average age-proportions were estimated from the initial brood year in the time series to the 1977 brood year (typically brood years 1948-1977). For jack-knife forecasts post-1978, average age-proportions were estimated from the 1978 brood year to the last year brood year in the time-series (typically brood years 1978-2004). When using the cyclic Ricker model, age-proportions were independently calculated for the four year old brood year and five year old brood year cycle lines, using the same time-periods.

To ensure consistent comparisons of performance across models, particular years were removed from the jack-knife forecast time-series for each stock. Specifically, since certain non-parametric models (R1C, R2C, RS1, RS2, RS4yr, RS8yr) require stock-recruitment data from previous years to generate a forecast, the first eleven years were removed. In addition, for particular stocks with missing data points in their escapement time-series, a number of years were removed from the jack-knife forecast time-series, to account for the number of consecutive years of data required by some models (example: the RS8yr model requires 8 years of consecutive EFS data, plus there is a 3-year lag in recruitment data availability). In the case of Cultus, several models (RJ1, RJ2, RJC, RJ4yr and RJ8yr) were removed from consideration due to considerable gaps in the juvenile time-series.

2.3.2 Performance Measures

The jackknife time series' of forecasts for each stock were used to calculate four performance measures (PM's) to rank each model's performance: mean raw error (MRE), mean proportional error (MPE), mean absolute error (MAE) and root mean square error (RMSE) (Cass et al. 2006; Haeseker et al. 2007 and 2008; see Appendix 4 in Grant et al. 2010). Each performance measure evaluates a different component of a model's forecasting ability. Specifically, MRE evaluates model bias (i.e. does a model, on average, consistently over or under forecast true returns), MAE evaluates precision (i.e. on average, how close is a model's forecast to true returns), MPE evaluates relative precision (i.e. on average, how close is a model's forecast to true returns, standardized by true return size), and RMSE evaluates accuracy (i.e. evaluates variance in the difference between the forecasts and true returns). For each of these measures, smaller values indicate better model performance. Performance measures were calculated for each stock and model using the full jack-knife forecast time-series, excluding the years removed for consistency, and paired observed returns (brood years 1959-2004).

2.3.3 Model Selection Methods

For each stock, models were ranked based on their relative performance to each other on each of the four performance measures (smaller performance measure values are more precise and/or accurate depending on the performance measure). The better a model's relative performance, the higher it will rank, with one indicating the best performing model. Ranks across the four performance measures were then averaged to generate an average rank for each model evaluated (Table 5). Forecasts for 2012 were generated for the top three ranked models for each stock (based on their average rank) (Table 6).

Next, to ensure that selected models did not rank poorly on a single performance measure, since each measure describes different characteristics of model performance (accuracy and/or precision), the top ranked models for each stock were evaluated for consistent performance across each of the four individual performance measures (MRE, MAE, MPE and RMSE). For each stock, models that did not consistency rank within the top half of all models (e.g. if 20 models were evaluated, the models must rank within the top 10) on each performance measure (i.e. MRE, MAE, MPE and RMSE) were generally not considered. The model with the highest average rank that also ranked in the top half of all models across each of the individual performance measures was usually selected to generate the 2012 forecast, pending a final

comparison of brood year escapements and error checks described below. If, however, a model ranked first on the average rank criterion but did not rank within the top 50% for each individual performance measure, a lower (second or third) average ranked model was selected for further evaluation.

After comparing overall model ranks and ranks across individual performance measures, the 2008 brood year escapement (or juvenile abundances) for each stock was compared to its cycle average. If brood year escapements (or juvenile abundances) were above or below the cycle average (bounds on the average range were set the same as for the colour-coding, as described in the Biological Data section), only top ranked biological models, or non-parametric models that include escapement (or smolts/fry) as a predictor variable, were considered for the 2012 forecast.

Final error checks included a comparison of the 2012 stock-specific forecasts across all top-ranked models (Table 6), highlighting similarities and differences in forecasts. In addition, the four year old productivities associated with each forecast were compared to averages for each stock, to analyze where forecast productivities fall out in terms of recent and long-term observed stock productivities (Table 2).

3 FORECAST RESULTS

3.1 OVERVIEW OF THE 2012 FRASER SOCKEYE RETURN

Fraser Sockeye forecasts for 2012 are associated with relatively high uncertainty, consistent with previous Fraser Sockeye forecasts (Cass et al. 2006; DFO 2006; DFO 2007; DFO 2009; Grant et al. 2010; DFO 2012; Grant and MacDonald 2012) and recent research conducted on coast-wide salmon stocks (Haeseker et al. 2007 and 2008). Given the absence of leading quantitative or qualitative indicators of Fraser Sockeye survival, stochastic (random) uncertainties associated with the 2012 Fraser Sockeye forecasts are presented as a series of forecasted values that correspond to standardized cumulative probabilities (10%, 25%, 50%, 75%, and 90%). The 50% (median) probability level is the mid-point of the forecast distribution, indicating a one in two chance that Fraser Sockeye return abundances will be above or below these values, assuming survival is similar to past observations.

The 2012 forecast indicates a one in ten chance (10% probability) that the total Fraser Sockeye return will be at or below 750,000, and a nine in ten chance (90% probability) it will be at or below 6.6 million, assuming survival is similar to past observations. The mid-point of this distribution (50% probability) is 2.1 million (there exists a one in two chance that the return will be above or below this value) (Table 1; Figure 3). Productivities associated with these forecasts are presented in Table 2. The Fraser Sockeye return forecast for 2012 is dominated by Summer Run stocks (contributing 67% to the total forecasted return) (Table 1). In particular, Chilko (27%), Late Stuart (16%) and Stellako (11%) contribute the greatest proportions. In contrast, most Fraser Early Summer and Late Run stocks exhibited amongst the lowest brood year escapements on record in 2008 (brood year for four year old returns in 2012), therefore, forecasts for each of these run timing groups contribute little (Early Summer: 17% and Late: 11%) to the overall 2012 Fraser Sockeye forecast. The Early Stuart Run contributes only 5% to the total forecast despite its average brood year escapement, as this is a subdominant cycle year for this stock. The forecasted return for Cultus Sockeye, listed as 'endangered' by the Committee for Endangered Wildlife in Canada (COSEWIC), is smaller than the previous few years, given the low number of outmigrating smolts in the brood year (2008: ~145,000) versus previous brood years (2006 and 2007: ~400,000). The forecasted 2012 Fraser Sockeye return falls largely (probability levels ≤ 75%) below the cycle average (3.8 million) (Figure 3). This below average return is attributed to the well below average 2008 brood year escapements observed particularly for the Early Summer and Late Run stocks. Given these low brood year

escapements, if Fraser Sockeye productivity returns to the low trend of recent decades, the 2012 return has the potential to be amongst the lowest observed on this cycle. Conversely, there is a small chance (one in four) the return could be above the cycle average if stock productivities fall at the high end of past observations. Additionally, due to the low escapements of 2008 (which produce four year olds in 2012) relative to 2007 (which produce five year olds in 2012), the forecasted proportion of total four year old returns (~75%) is below average (82% average four year old proportion for all stocks combined, excluding Harrison). Four year old proportions ranged from 10% to 98%, depending on the stock.

3.2 INDIVIDUAL STOCK FORECASTS

3.2.1 Early Stuart Run

The 2008 brood year is one of three 'off cycle' years for the Early Stuart stock, with 2005 falling on the dominant cycle. The 2008 escapement of 14,400 EFS for Early Stuart was close to the cycle average of 19,800 EFS (brood years 1948-2004) (Table 1, column C).

Physical conditions (water levels and temperature) on the spawning grounds were within an acceptable range for successful spawning during the 2008 Early Stuart spawning season. However, crews observed higher than normal levels of egg retention in female carcasses resulting in higher than average estimates of pre-spawn mortality. Spawning success averaged 88% for the Early Stuart populations, falling below both the long-term cycle average (92%) and the brood year (98%).

Average total productivity (R/EFS) for Early Stuart has declined steadily from a peak during the mid-1960's of 35 R/EFS (Grant et al. 2010). In both the last four (2002-2005: 2.1 R/EFS) and last eight brood years (1998-2005: 2.5 R/EFS) (Table 2, columns E and D), average productivity for four year old fish has been approximately one quarter of the early time series average (brood years 1948-1979: 9.5 R/EFS) (Table 2, column B).

For Early Stuart, the top ranked models (based on the average rank across all four performance measures: MRE, MAE, MPE, RMSE) are the Ricker (Ei) (tied first), Ricker (Pi) (tied first), Ricker (tied third), and Ricker (PDO) (tied third) (Table 5). For each individual performance measure, these models each ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5). Forecasts produced by the top ranked models were similar, with the smallest forecast (Ricker (Pi)) deviating by 11% from the largest forecast (Ricker (Ei)) (percent difference between smallest and largest forecasts at the 50%-median probability level, calculated as a percentage of the largest forecast) (Table 6). The Ricker (Ei) model was used for the 2012 Early Stuart forecast, as it ranked first on average across performance measures, and it outperformed the other first-ranked model (Ricker (Pi)) on two of the four individual performance measures (and tied on one) (Table 5). Given the assumptions underlying the Ricker (Ei) model, there is a one in four chance (25% probability) the Early Stuart Sockeye return will be below 61,000 (4.1 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 161,000 (11.0 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 99,000 (6.7 age-4 R/EFS) is similar to the average return on this cycle (120,000) (Tables 1 and 2). The five year old component of the 2012 return is expected to contribute 2% of the total forecasted return (at the 50% probability level) (Table 3).

**Note: For the remaining stock sections the following were consistently applied: top ranked model forecasts were compared according to the percent difference between smallest and largest forecasts at the 50%-median probability level (calculated as a percentage of the largest forecast); unless otherwise noted, in all subsequent sections the top three models each ranked within the top half of all models compared for the stock; also, comparisons of ranks on individual performance measures refer only to the top three models.*

3.2.2 Early Summer Run

The Early Summer Run consists of a number of less abundant stocks relative to the more abundant Summer and Late Run stock groups. Eight stocks in this timing group are forecast using the standard suite of forecast models: Bowron, Fennell, Gates, Nadina, Pitt, Raft, Scotch, and Seymour (Table 1). Escapement in the 2008 brood year for all of these stocks combined was 21,900 EFS, which is less than half the long term cycle average of 47,800 EFS.

Only two of the eight Early Summer stocks had 2008 brood year escapements (EFS) that were close to their cycle averages (Nadina and Raft). Pitt Sockeye, comprised of predominantly five year old recruits, had an above average brood year escapement for the 2007 brood year. The remaining five stocks (Bowron, Fennell, Gates, Scotch and Seymour) had 2008 brood year escapements that were amongst the lowest of their entire time series. The total 2008 brood year EFS for the Early Summer Run, including the miscellaneous stocks (miscellaneous South Thompson, miscellaneous North Thompson, North Thompson River, Dolly Varden/Chilliwack Lake, and Nahatlatch) was 43,500. The Dolly Varden/Chilliwack Lake miscellaneous stock, in particular, contributed close to 50% of the total 2008 brood year EFS for all Early Summer Run stocks combined.

Physical conditions (water levels and temperature) on the Early Summer Run aggregate spawning grounds in 2008 were mostly adequate for spawning, with the exception of the Upper Adams River, where water levels were very high during the early portion of the run. Pre-spawn mortality was abnormally high across all Early Summer stocks throughout the spawning period (increasing particularly near the end of the migratory period for this run timing group). The resulting spawning success was the lowest on record, ranging from 23% (Gates) to 77% (Bowron), with an average of 45% across stocks, compared to the time-series average of 85%. The lowest success (1.4%) was observed in the Nadina system (Nadina Channel), where Sockeye were found approximately two weeks earlier than normal. Preliminary results from spawning ground sampling at Nadina and Gates indicate a high occurrence of Ich (*Ichthyophthirius multifilis*) infection. Upper Pitt Sockeye, comprised of predominantly five year old recruits, were in good condition on the spawning grounds, and exhibited high spawning success (99%) in the 2007 brood year.

<u>Bowron</u>

The 2008 brood year escapement for Bowron (300 EFS) was less than 10% of the long-term cycle average (1948-2004 average: 4,000 EFS), and is the lowest on record for this stock. (Table 1, column C). In recent years brood years (2002-2005), average four year old productivity (2.3 R/EFS) has been about 25% of the early time series average prior to 1980 (brood years 1948-1979: 9.0 R/EFS) (Table 2, columns E and B).

For Bowron, the top ranked models are the KF, MRS and Ricker (Pi) (Table 5). Forecasts produced by the top ranked models were not similar, varying by as much as 60% (Table 6). The KF model produced the lowest forecast, since it incorporates recent stock productivity (below average for Bowron) in generating return forecasts. The KF model was used for the 2012 Bowron forecast, as it ranked first on average across performance measures, and it ranked first on each individual performance measure except MRE (ranked 8th) (Table 5). Given the assumptions underlying the KF model, there is a one in four chance (25% probability) the Bowron Sockeye return will be below 1,000 (2.2 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 4,000 (7.3 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 2,000 (4.4 age-4 R/EFS) is well below the average return on this cycle (27,000) (Tables 1 and 2). The five year old component of the 2012 return is expected to contribute 50% of the total forecasted return (at the 50% probability level) (Table 3).

Fennell

The 2008 brood year escapement for Fennell (200 EFS) was less than 4% of the cycle average (5,500 EFS) from 1968-2004 (Table 1, column C), and can be attributed to the combination of below average escapement and extremely low spawning success (19%). Although productivity for Fennell has systematically declined since the mid-1970's (average productivity pre-1980: 20.0 R/EFS), four year old productivity in the last four to eight brood years (2002-2005: 3.2 R/EFS; 1998-2005: 4.0 R/EFS) was similar to the recent average (brood years 1980-2005 average: 4.1 R/EFS) (Table 2, columns B, E, D, and C).

For Fennell, the top ranked models are the power, RAC, KF (tied third) and Ricker (tied third) models (Table 5). Forecasts produced by the top ranked models were not similar, varying by as much as 78% (Table 6). This difference in forecasts is attributed to the relatively large forecast generated by the non-parametric RAC model, which does not use the extremely low 2008 brood year EFS for this stock as a predictor variable, unlike the biological models. The power model was used for the 2012 Fennell forecast, as it ranked first on average across performance measures, and, with the exception of the RAC model, it ranked as well as, or better than other top ranked models on each individual performance measure except MAE (ranked third) (Table 5). Given the assumptions underlying the power model, there is a one in four chance (25% probability) the Fennell Sockeye return will be below 7,000 (10.5 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 20,000 (34.8 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 12,000 (19.0 age-4 R/EFS) is well below the average return on this cycle (34,000) (Tables 1 and 2). The five year old component of the 2012 return is expected to contribute 66% of the total forecasted return (at the 50% probability level) (Table 3).

Gates

The 2008 brood year escapement for Gates (1,800 EFS) was well below the cycle average (9,900 EFS) from 1968-2004 (Table 1, column C), and can be attributed to the combination of below average escapement and extremely low spawning success (23%). In recent brood years (2002-2005), average four year old productivity (3.1 R/EFS) was less than 20% of the early time series average prior to 1980 (brood years 1968-1979: 17.0 R/EFS) (Table 2, columns E and B). Gates juvenile fry data, which provide an index of juvenile abundance, indicate that early freshwater survival for the 2008 brood year (1,200 fry/EFS) was also below the cycle average (1,600 fry/EFS).

For Gates, the top ranked models are the KF, RAC and R2C models (Table 5). For each individual performance measure, the KF and RAC models each ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5). These two models, however, produced widely different forecasts from one another, diverging by 91% (Table 6). The RAC model produced a much higher forecast than the KF model, as this model does not include the extremely low 2008 brood year EFS or the recent low productivity observed for this stock as a predictor variable. The KF model was used for the 2012 Gates forecast, as it ranked first on average across performance measures, it ranked well on each individual performance measure, and it takes the low brood year escapement into consideration. The KF model, however, does not rank highest across individual performance measures (Table 5). Given the assumptions underlying the KF model, there is a one in four chance (25% probability) the Gates Sockeye return will be below 6,000 (3.1 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 21,000 (11.0 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 12,000 (6.0 age-4 R/EFS) is less than one tenth of the average return on this cycle (135,000) (Tables 1 and 2). The five year old component of the 2012 return is expected to contribute 8% of the total forecasted return (at the 50% probability level) (Table 3).

Nadina

The 2008 brood year escapement for Nadina (10,200 EFS) was close to the cycle average (13,700 EFS) from 1976-2004 (Table 1, column C). Juvenile fry data, used as an index of juvenile abundance, indicate that early freshwater survival in the 2008 brood year (1,200 fry/EFS) was average for this cycle (1,200 fry/EFS) and juvenile abundance (12.2 million fry) was near average (1976-2004 average: 13.7 million fry). Although total productivity has systematically declined for Nadina since the mid-1960's, average four year old productivity over the last four brood years (2002-2005: 3.5 R/EFS) was still somewhat similar to the recent average (brood years 1980-2005 average: 5.3 R/EFS) (Table 2, columns E and C).

For Nadina, the top ranked models are the MRJ, Ricker (FrD-peak), and power (juv) (FrD-peak) (Table 5). These three models each ranked within the top 50% (17 out of 33 models) of all models compared for this stock for three of the four individual performance measures. However, all three models each ranked poorly (ranked ≥ 19 out of 33) on the MRE performance measure. Of the 33 models explored for Nadina, none ranked in the top 50% across all performance measures (all models either ranked well on MRE and poorly on all other performance measures, or vice versa). Therefore, the MRE performance measure was not used to inform model selection. Forecasts produced by the top ranked models varied at most by 23% (Table 6). The MRJ model was used for the 2012 Nadina forecast, as it ranked first on average across performance measures, and it ranked first on each individual performance measure except MRE (ranked 28th) (Table 5). Given the assumptions underlying the MRJ model, there is a one in four chance (25% probability) the Nadina Sockeye return will be below 33,000 (3.2 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 147,000 (14.2 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 70,000 (6.7 age-4 R/EFS) is half of the average return on this cycle (137,000) (Tables 1 and 2). The five year old component of the 2012 return is expected to contribute 3% of the total forecasted return (at the 50% probability level) (Table 3).

Pitt

Annual returns for Pitt have a greater proportion of five year old recruits (~70%) relative to other Fraser Sockeye stocks. Therefore, the five year old brood year makes a larger contribution to the returns in any given year for this stock. Due to the greater proportion of five year old recruits (~70%) relative to four year old recruits for Pitt, cyclic patterns of returns do not occur. Therefore, brood year escapements were compared to the time-series average, rather than the cycle average, for Pitt. The brood year escapement for Pitt in 2007 (for five year old recruits returning in 2012: 19,900 EFS) was above the average escapement from 1948-2009 (13,500 EFS). In contrast, the 2008 escapement (for four year old recruits returning in 2012: 5,400 EFS) was below average (13,500 EFS) (Table 1, columns D and C). Four year old productivity in the Pitt system was above average prior to 1980 (brood years 1948-1979: 2.6 R/EFS; 1948-2005: 1.4 R/EFS) and has subsequently declined on average (brood years 1980-2005 brood year average: 0.6 R/EFS). The past four to eight brood years show extremely low four year old productivity (2002-2005: 0.1 R/EFS; 1998-2005: 0.3 R/EFS), falling below replacement (Table 2, columns B, C, E and D). This decline has coincided with above-average escapements.

For Pitt, the top ranked models are the KF, Larkin and TSA models (Table 5). For each individual performance measure, the KF and Larkin models each ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5). Forecasts produced by these two models varied at most by 22% (Table 6). The KF model was used for the 2012 Pitt forecast, as it ranked first on average across performance measures, and it ranked first on each individual performance measure except MRE (ranked seventh) (Table 5). Given the assumptions underlying the KF model, there is a one in four chance (25% probability) the Pitt Sockeye return will be below 18,000 (0.2 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 65,000 (1.4 age-4 R/EFS) in 2012. The median (one in two chance: 50%

probability) forecast of 35,000 (0.6 age-4 R/EFS) is less than half of the average return on this cycle (81,000) (Tables 1 and 2). The five year old component of the 2012 return is expected to contribute 91% of the total forecasted return (at the 50% probability level) (Table 3). The five year old productivity associated with the 50% probability forecast for Pitt is 1.6 R/EFS.

Raft

The 2008 brood year escapement for Raft (3,600 EFS) was below the cycle average (7,100 EFS) from 1948-2004 (Table 1, column C). Although productivity for Raft has not exhibited systematic trends (average for brood years 1948-2005: 6.1 R/EFS), four year old productivity over the past four (2002-2005: 2.0 R/EFS) to eight brood years (2.7 R/EFS) has fallen to below half the long-term average (Table 2, columns B to E).

For Raft, the top ranked models are Ricker (PDO), Ricker-cyc (tied second) and power (tied second) (Table 5). For each individual performance measure, only the Ricker (PDO) model ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5). Forecasts produced by the three top ranked models varied at most by 39% (Table 6). The Ricker (PDO) model was used for the 2012 Raft forecast, as it ranked first on average across performance measures, and it ranked highest on each individual performance measure except RMSE (ranked fourth) (Table 5). Given the assumptions underlying the Ricker (PDO) model, there is a one in four chance (25% probability) the Raft Sockeye return will be below 34,000 (2.8 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 88,000 (9.2 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 55,000 (5.2 age-4 R/EFS) is very close to the average return on this cycle (57,000) (Tables 1 and 2). The five year old component of the 2012 return is expected to contribute 65% of the total forecasted return (at the 50% probability level) (Table 3).

Scotch

The 2008 brood year escapement for Scotch (140 EFS) was well below the cycle average (1,000 EFS) (Table 1, column C) from 1980-2004. Four year old productivity was greatest in the early time series (1980-1990 brood year average: 12.6 R/EFS). The recent average four year old productivity (brood years 1998-2005: 6.7 R/EFS) is the same as the long-term average (brood years 1980-2005: 6.7 R/EFS), though in the last four brood years productivity has been slightly lower (2002-2005: 3.5 R/EFS) (Table 2, columns D, C and E).

For Scotch, the top ranked models are the Larkin, Ricker and RS1 (Table 5). For each individual performance measure, the Larkin and Ricker models each ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5). Forecasts produced by the Larkin and Ricker models were not similar, varying by 80% (Table 6). The Larkin model forecast is smaller than the Ricker model, due to the Larkin model's consideration of delayed density-dependent interactions between the 2008 brood year escapement and the relatively high escapements of previous years for Scotch (Table 6). In particular, the escapement in 2006 (73,000 EFS) was the highest escapement on record for this stock. The Larkin model was used for the 2012 Scotch forecast, as it ranked first on average across performance measures, and it ranked highest on each individual performance measure except MRE (ranked fifth) (Table 5). Given the assumptions underlying the Larkin model, there is a one in four chance (25% probability) the Scotch Sockeye return will be below 200 (0.9 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 700 (4.0 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 300 (1.9 age-4 R/EFS) is extremely low compared to the average return on this cycle (12,000) (Tables 1 and 2). The five year old component of the 2012 return is expected to contribute 17% of the total forecasted return (at the 50% probability level) (Table 3).

Seymour

The 2008 brood year escapement for Seymour (300 EFS) was less than 10% of the cycle average (4,200 EFS) from 1948-2004 (Table 1, column C). Productivity has been variable throughout the time series for this stock, with a general declining trend from the earlier time series (brood years 1948-1979 average R/EFS: 10.9) to more recent brood years (1980-2005 average: 5.1 R/EFS; 2002-2005 average: 3.6 R/EFS) (Table 2, columns B, C and E).

For Seymour, the top ranked models are the Ricker-cyc, R1C (tied second) and Larkin (tied second) (Table 5). For each individual performance measure, the Ricker-cyc and R1C models each ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5). Forecasts produced by these two models were similar, varying by only 5% (Table 6). The Ricker-cyc model was used for the 2012 Seymour forecast, as it ranked first on average across performance measures, and it outperformed the R1C model on three of four performance measures (ranked second on MRE) (Table 5). Given the assumptions underlying the Ricker-cyc model, there is a one in four chance (25% probability) the Seymour Sockeye return will be below 4,000 (3.9 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 16,000 (13.0 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 8,000 (7.4 age-4 R/EFS) is well below the average return on this cycle (34,000) (Tables 1 and 2). The five year old component of the 2012 return is expected to contribute 75% of the total forecasted return (at the 50% probability level) (Table 3).

3.2.3 Summer Run

The Summer Run consists of four stocks: Chilko, Late Stuart, Quesnel and Stellako (Table 1). Escapement in the 2008 brood year for these four stocks combined (202,900 EFS) was below the long-term cycle average (364,200 EFS). Each of Chilko (34%), Late Stuart (29%) and Stellako (36%) contributed approximately one third to the Summer Run total EFS. In contrast, the contribution of Quesnel was negligible (1%). Physical conditions (water levels and temperature) on the Summer Run aggregate spawning grounds in 2008 were acceptable. However average spawning success for the group (69.5%) was well below the historical average.

Chilko

The 2008 brood year escapement for Chilko (68,700 EFS) was 25% of the cycle average (275,800 EFS) from 1948-2004. The Chilko system experienced the lowest spawning success (52%) of the Summer Run aggregate, well below the long-term average (97%). Chilko smolt data indicate that freshwater survival for the 2008 brood year (172 smolts/EFS) was above the cycle average (103 smolts/EFS) (Figure 2 A). Juvenile (smolt) abundance in the 2008 brood year (11.8 million age-1 smolts) was below the long-term (brood years 1952-2004) cycle average (22.5 million age-1 smolts) (Table 1, column C), and the recent (brood years 1980-2004) cycle average (18.2 million age-1 smolts). Smolt abundance in the previous (2007) brood year, for the five year old Sockeye returning in 2012, was 25.2 million one year old (sub2) smolts, higher than the long-term average on that cycle (1951-2003 average: 19.9 million one year old smolts). Smolt body sizes in the 2008 (91.3 mm) and 2009 (83.0 mm) brood years were, respectively, above, or near-identical to the long-term (brood years 1953-2009) average (83.2 mm).

Marine four year old survival for Chilko has been particularly low in the last four to eight brood years (2% marine survival) relative to the long term average (1949-2005: 7%) (Table 2, columns D and E; Figure 2 B). The highest period of marine survival on record occurred from 1980-1990 (10% marine survival) (Figure 2 B). Conversely, the four year old marine survival observed in the 2009 Chilko returns, was the lowest on record (0.3%), coinciding with an unprecedented number of Chilko smolts in the 2005 brood year (77 million one year old smolts).

For Chilko, the top ranked models are the KF (juv), power (juv) (Pi) (tied second), and Larkin (tied second) (Table 5). For each individual performance measure, none of these models ranked within the top 50% (17 out of 33) of all models compared for this stock (Table 5). All three models ranked poorly on MRE. Of the 33 models explored for Chilko, none (with the exception of MRJ) ranked in the top 50% across all performance measures (most models ranked well on MRE and poorly on all other performance measures, or vice versa), therefore the MRE performance measure was not used to inform model selection (Table 5). Forecasts produced by the top ranked models varied by as much as 48% (Table 6). The KF (juv) generated the lowest forecast, reflecting this stocks recent lower productivity. The KF (juv) model was used for the 2012 Chilko forecast, as it ranked first on average across performance measures (Table 5). Given the assumptions underlying the KF (juv) model, there is a one in four chance (25% probability) the Chilko Sockeye return will be below 342,000 (2% age-4 marine survival) and a three in four chance (75% probability) the return will be below 868,000 (6% age-4 marine survival) in 2012. The median (one in two chance: 50% probability) forecast of 562,000 (4% age-4 marine survival) is well below the average return on this cycle (1,790,000) (Tables 1 and 2). The five year old component of the 2012 return is expected to contribute 22% of the total forecasted return (at the 50% probability level) (Table 3).

Late Stuart

The 2008 brood year is the third of three smaller (weak) cycles for Late Stuart, following the dominant cycle in 2005. However, the 2008 brood year escapement (57,900 EFS) was more than double the cycle average (23,600 EFS) from 1952-2004 (Table 1, column C). Spawning success in the Late Stuart system was 79% in 2008, below the long-term average of 92%. Four year old productivity was variable up to the 1979 brood year (average: 11.3 R/EFS) (Table 2, column B), and has declined in recent brood years (1998-2005 average four year old productivity: 2.6 R/EFS) (Table 2, column D).

For Late Stuart, the top ranked models are the R1C, R2C and power (Table 5). For each individual performance measure, the R1C and R2C models each ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5). Forecasts produced by the top ranked models varied by as much as 53% (Table 6). The R2C forecast was larger than forecasts produced by the other two models, based on the large return to the Late Stuart system in 2004. Since the brood year escapement for Late Stuart was above average, the biological model (power) was used to generate the 2012 forecast, as this is the only top ranked model that incorporates EFS as a predictor variable in generating the forecast (Table 5). Given the assumptions underlying the power model, there is a one in four chance (25% probability) the Late Stuart Sockeye return will be below 166,000 (2.6 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 730,000 (12.4 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 338,000 (5.6 age-4 R/EFS) is greater than, but within the average range, of the average return on this cycle (187,000) (Tables 1 and 2). The five year old component of the 2012 return is expected to contribute 5% of the total forecasted return (at the 50% probability level) (Table 3).

Quesnel

The 2008 brood year escapement for Quesnel (2,500 EFS) was half the cycle average (5,000 EFS) from 1948-2004 (Table 1, column C), however due to the wide variability in Sockeye abundances on this cycle, the brood year escapement still fell within the average range (0.5 standard deviations from the cycle average). Spawning success in the 2008 brood year (59%) was well below average (85%). This brood year is the second 'off-cycle' year following the dominant 2005 and sub-dominant 2006 brood year cycles. Fry assessments were not conducted in Quesnel for the 2008 brood year (2009 fry survey year). Four year old productivity for Quesnel on the 2008 cycle has declined in the past eight brood years (2000 and 2004

average: 1.0 R/EFS) relative to the 1980-2004 brood year cycle average (4.8 R/EFS) and the long term cycle average (brood years 1948-2004 average: 7.2 R/EFS) (Table 2, columns D and C).

For Quesnel, the top ranked models are the R1C, R2C and KF (Table 5). For each individual performance measure, the R1C and R2C models each ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5). Forecasts produced by these two top models varied by as much as 59% (Table 6). The R2C forecast was larger than forecasts produced by the other two models, based on the large return to the Quesnel system in 2004. The R1C model was used for the 2012 Quesnel forecast, as it ranked first on average across performance measures, and it out ranked the R2C model on three out of four individual performance measures (ranked second on MPE) (Table 5). Given the assumptions underlying the R1C model, there is a one in four chance (25% probability) the Quesnel Sockeye return will be below 33,000 (3.1 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 137,000 (12.9 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 67,000 (6.3 age-4 R/EFS) is similar to the average return on this cycle (57,000) (Tables 1 and 2). The five year old component of the 2012 return is expected to contribute 76% of the total forecasted return (at the 50% probability level) (Table 3).

<u>Stellako</u>

The 2008 brood year escapement for Stellako (73,800 EFS) was above the cycle average (61,400 EFS) from 1948-2004 (Table 1, column C). Stellako four year old productivity has declined in recent years (average of 1998-2005 brood years: 1.5 R/EFS) relative to the productivity of earlier years (average of 1948-1979 brood years: 10.1 R/EFS) (Table 2, columns D and B). In the last four brood years (2002-2005) Stellako has experienced particularly low four year old productivity (average: 0.7 R/EFS) (Table 2, column E).

For Stellako, the top ranked models are the R2C, Larkin and KF (Table 5). For each individual performance measure, the R2C and KF models each ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5). Forecasts produced by the top ranked models varied by as much as 51% (Table 6). The KF model, in particular, produced a lower forecast, reflecting this stocks recent lower productivity. The R2C model was used for the 2012 Stellako forecast, as it ranked first on average across performance measures, and it ranked high on each individual performance measure (Table 5). Given the assumptions underlying the R2C model, there is a one in four chance (25% probability) the Stellako Sockeye return will be below 287,000 (3.5 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 714,000 (8.6 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 453,000 (5.4 age-4 R/EFS) is very similar to the average return on this cycle (467,000) (Tables 1 and 2). The five year old component of the 2012 return is expected to contribute 11% of the total forecasted return (at the 50% probability level) (Table 3).

3.2.4 <u>Late Run</u>

The Late Run consists of six stocks: Cultus, Harrison, Late Shuswap, Portage, Weaver, and Birkenhead (Table 1). The total escapement for the Late Run aggregate in 2008 was the lowest on record for this run timing group (all cycles), with only 12,000 EFS (excluding Cultus). This escapement was well below the cycle average of 58,000 EFS (Table 1). The miscellaneous Late Run stocks (e.g. Harrison Lake rearing stocks) brood year EFS was 900 (Table 1).

The median upstream migration date past the lower river in 2008 was the earliest on record for a number of Late Run Sockeye stocks (Late Shuswap, Weaver, Harrison). However, early arrival of Late Run stocks was not observed on the terminal spawning grounds, with the exception of Cultus. Elevated levels of en-route mortality were observed in the Lower Fraser mainstem and the Harrison-Lillooet terminal area, and spawning success for the Late Run aggregate stocks in the 2008 brood year (72%) was below average. Conditions in the

watershed were favorable for spawning throughout the spawning period (i.e. acceptable water temperatures and levels).

Cultus

Total Cultus Sockeye escapement (counted through the Sweltzer Creek enumeration fence) in the 2008 brood year (360 Sockeye: jacks plus adults) was the second lowest on record for this cycle. In 2008, 84% percent of Cultus Sockeye that returned to the enumeration fence were adipose fin clipped (hatchery origin). Cultus Sockeye have been exhibiting early migration since the mid-1990's, and the migration timing to the Cultus fence in 2008 was the earliest on record for this stock. Very few female Sockeye carcasses were recovered in the 2008 brood year (<10), therefore the extremely low spawner success estimate (14%) is highly uncertain. Hatchery supplementation of both fry into Cultus Lake and smolts into Sweltzer Creek (downstream of the enumeration fence) has increased the number of outmigrating smolts since the hatchery program commenced in the 2000 brood year. However, despite hatchery contributions to the 2008 brood year (99.8% of the total outmigrating smolts were hatchery origin), smolt numbers (145,000) were much lower than the long-term cycle average (480,000) (Table 1). Four year old marine survival for Cultus has been particularly low in the last eight brood years (2% marine survival), relative to the 1980-2005 average (4%) (Table 2, columns D and C). At the time of this publication, only jack (three year old Sockeye) escapement (not return) data were available for Cultus from the 2008 brood year (2011 return year). Cultus preliminary jack escapement was ~300 fish, which is below the time series (1948-2004) average for age-3 recruits (1,000), and is close to the recent (1980-2004) average (200).

For Cultus, the top ranked models are the KF (juv), MRJ, and power (juv) (FrD-peak) (Table 5). Only 14 models were considered in the model ranking process for Cultus because significant gaps in the smolt time-series severely restricted the number of years that could be forecasted by certain smolt models (RJ1, RJ2, RJC, RJ4yr and RJ8yr) with jack-knife analysis. In addition, all models that use EFS as a predictor variable were excluded, as EFS data for Cultus do not take into consideration the significant hatchery supplementation (fry and smolts) that has occurred for this stock starting in the 2000 brood year. Forecasts produced by the top ranked models were not similar, varying by as much as 61% (Table 6). The KF (juv) model generated the lowest forecast, reflecting this stocks recent lower productivity. In contrast, the MRJ produced the highest forecast since it uses the time series average productivity to generate the forecast. The KF (juv) model was used for the 2012 Cultus forecast, as it ranked first on average across performance measures, and it ranked first on each individual performance measure (Table 5). Given the assumptions underlying the KF model, there is a one in four chance (25% probability) the Cultus Sockeye return will be below 1,000 (1% age-4 marine survival) and a three in four chance (75% probability) the return will be below 7,000 (5% age-4 marine survival) in 2012. The median (one in two chance: 50% probability) forecast of 3,000 (2% age-4 marine survival) is well below the average return on this cycle (21,000) (Tables 1 and 2). The five year old component of the 2012 return is expected to contribute 0% of the total forecasted return (at the 50% probability level) (Table 3).

Harrison

Harrison Sockeye have a unique age structure and life history compared to other Fraser Sockeye stocks. Harrison Sockeye return predominantly as three and four year old fish (most Fraser Sockeye return as four and five year old fish) having migrated to the ocean shortly after gravel emergence (most Fraser Sockeye rear in lakes for one to two years after gravel emergence prior to their ocean migration). Proportions of Harrison three and four year old recruits vary considerably inter-annually, with four year old proportions ranging from 10% to 90% of total recruits (Grant et al. 2010). Odd brood years, on average, produce a higher proportion of four year old recruits, and even years produce a higher proportion of three year old

recruits (Grant et al. 2010). Harrison Sockeye EFS abundance in the 2008 (4,400 EFS) brood year (four year old recruits in 2012) was well below the time series average (13,500 EFS). In contrast, the 2009 brood year (100,600 EFS) (three year old recruits in 2012) was the second largest total escapement on record for this stock. Escapements for Harrison Sockeye are compared to the entire time series instead of the cycle average, which is used for stocks that are comprised predominantly of four year old returns (Table 1, columns C and D).

Conditions in the Harrison system in the 2008 (age 4 (4_1) returns in 2012) and 2009 (three year old returns (3_1) in 2012) brood years were favorable, and spawning success in these years was, respectively, 100% and 94%. Four year old productivity (age-4 recruits/EFS) has generally increased, from the early time series average of 2.3 age-4 R/EFS (1948-1979) to an average of 6.3 age-4 R/EFS in the last 8 brood years (1998-2005) (Table 2, columns B and D). For the 2005 brood year, similar to all other Fraser Sockeye stocks from the same brood year, productivity was the lowest on record (Grant et al. 2010).

Harrison Sockeye have been extremely challenging to forecast in recent years, given large increases in escapements and productivity (Grant et al. 2010; Grant et al. 2011). Historically (up to the year 2000), escapements averaged 6,500 EFS, while total productivity remained around 15 R/EFS. In recent years, however, productivity has systematically increased (Grant et al. 2010; Grant et al. 2011). Two recent years, in particular, have exhibited widely variable productivity: the 2004 brood year total productivity was the highest on record (140 R/EFS: 140,000 recruits/1,000 EFS) and the 2005 brood year total productivity was the lowest on record (0.07 R/EFS; 14,000 recruits/200,000 EFS). The most recent brood year total productivity (2006 brood year) was average (15 R/EFS) despite a well above average brood year escapement (90,000), which would be expected to result in a decrease in productivity due to density-dependence (based on historical data). Although differences in odd versus even year age proportions are considered in the Harrison forecast models, age proportions can vary considerably and, therefore, contribute to higher uncertainty in Harrison forecasts relative to other Fraser Sockeye stocks.

For Harrison, the top ranked models are the Ricker (Ei), KF, Ricker (FrD-peak) and R2C (Table 5). For each individual performance measure, only the KF model ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5). Forecasts produced by the top ranked models varied by 41% (Table 6). The KF model produced the largest forecast, reflecting recent increases in productivity for this stock. The KF model was used for the 2012 Harrison forecast, as it ranked second on average across performance measures, and it ranked high on each individual performance measure (Table 5). Given the assumptions underlying the KF model, there is a one in four chance (25% probability) the Harrison Sockeye return will be below 39,000 (3.4 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 184,000 (23.4 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 83,000 is above the average return on this cycle (19,000) (8.9 age-4 R/EFS) (Tables 1 and 2). The three year old component of the 2012 return is expected to contribute 53% of the total forecasted return (at the 50% probability level) (Table 3). Despite the high brood year escapement for three year olds returning in 2012 (2009 brood year), relative to the four year old brood year escapement (2008 brood year), the three year old contribution to the 2012 return is lower than would be anticipated. This is attributed to the relatively low post-1980 three year old proportion of total recruits (three plus four year olds), which is only 26%.

Late Shuswap

The 2008 brood year was an 'off-cycle' year for the highly cyclic Late Shuswap stock. Escapement for Late Shuswap in the 2008 brood year (80 EFS) was the lowest on record, and was less than 3% of the cycle average (1948-2004: 3,100 EFS) (Table 1, column C). Spawning success was not assessed for this stock in 2008, given the extremely low brood year EFS and, therefore, negligible number of carcasses recovered. The estimate of 80 EFS assumed 100%

spawning success. Fry assessments were not conducted for Late Shuswap in the 2008 brood year (2009 fry assessment year). Average four year old productivity on the 2008 cycle has dropped in recent years, relative to the pre-1980 reference period (1948-1979 average: 5.9 R/EFS) and the long-term cycle average from 1948-2004 (5.0 R/EFS) (Table 2, columns B-E). The average over the last two cycle brood years was 2.4 R/EFS (2000 and 2004), with particularly low four year old productivity for the 2004 brood year (0.7 R/EFS) (Table 2, columns D and E).

For Late Shuswap, the top ranked models are the R1C, Ricker-cyc, and RAC (Table 5). Forecasts produced by the top ranked models were not similar, varying by up to 70% (Table 6). The R1C and Ricker-cyc models produced similar low forecasts, reflecting, respectively, the poor return and the poor escapement of 2008 (Table 5). Given the extremely low 2008 brood year escapement for Late Shuswap, the top ranked biological model (Ricker-cyc) was used to generate this forecast, as this model, unlike the first and third ranked non-parametric models, uses brood year escapement as a predictor variable. The Ricker-cyc model also ranked high on average across performance measures, and it ranked high on each individual performance measure (Table 5). Given the assumptions underlying the Ricker-cyc model, there is a one in four chance (25% probability) the Late Shuswap Sockeye return will be below 3,000 (0.0 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 19,000 (4.8 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 8,000 (1.2 age-4 R/EFS) is well below the average return on this cycle (29,000) (Tables 1 and 2). The five year old component of the 2012 return is expected to contribute 99% of the total forecasted return (at the 50% probability level) (Table 3).

Portage

The 2008 brood year escapement for Portage (60 EFS) was the lowest on record, and was less than one tenth of the cycle average (1956-2004: 630 EFS) (Table 1, column C). Spawning success in 2008 (85%) was also below average (94%). Four year old productivity was particularly high in the first part of the time series with an average of 20.9 R/EFS over the brood years 1953-1979 (Table 2, column B). Subsequently, between the 1980 and 2005 brood years, four year old productivity has been consistently lower (average of 8.8 R/EFS) (Table 2, column C). The most recent four brood years (2002-2005) had particularly low four year old productivity for this stock (2.2 R/EFS) (Table 2, column E).

For Portage, the top ranked models are the Larkin, KF (tied second), and Ricker-cyc (tied second) (Table 5). For each individual performance measure, the Larkin and Ricker-cyc models each ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5). Forecasts produced by these two top models were similar, varying by 10% (Table 6). The KF model generated the lowest forecast of the top ranked models, reflecting the recent decline in productivity for this stock. The Larkin model was used for the 2012 Portage forecast, as it ranked first on average across performance measures, and it ranked well on each individual performance measure (Table 5). Given the assumptions underlying the Larkin model, there is a one in four chance (25% probability) the Portage Sockeye return will be below 1,000 (7.9 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 4,000 (41.3 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 2,000 (19.0 age-4 R/EFS) is well below the average return on this cycle (16,000) (Tables 1 and 2). The five year old component of the 2012 return is expected to contribute 40% of the total forecasted return (at the 50% probability level) (Table 3).

Weaver

The 2008 brood year escapement for Weaver (600 EFS) was the lowest on record, and was less than 3% of the cycle average (1968-2004: 21,900 EFS) (Table 1, column C). The Weaver stock experienced elevated en-route mortality from Late August to early September 2008, and spawning success was low in the channel (74%) and creek (7%) compared to the long-term averages (92% and 89%, respectively). Early freshwater survival in the 2008 brood year (2,300 fry/EFS) was greater than the cycle average (1,600 fry/EFS). However, juvenile abundance (1.4 million fry) was well below the 2008 cycle average (1968-2004 average: 33.4 million fry). Four year old productivity has been relatively consistent over the time series (brood years 1966-1979 average: 15.2 R/EFS; brood years 1980-2005 average: 10.2 R/EFS), though it has decreased in recent years (brood years 2002-2005 average: 3.9 R/EFS) (Table 2, columns B-E).

For Weaver, the top ranked models are the RS4yr, MRS, and Ricker (PDO) (Table 5). For each individual performance measure, only the RS4yr model ranked within the top 50% (17 out of 33) of all models compared for this stock (Table 5). Forecasts produced by the top ranked models varied by 44% (Table 6). The Ricker (PDO) model generated a forecast that was 1.6 x greater than the standard Ricker model (the Ricker model with no environmental covariate produced a forecast similar to the RS4yr model). The RS4yr model was used for the 2012 Weaver forecast, as it ranked first on average across performance measures, and it ranked relatively high on each individual performance measure (Table 5). Given the assumptions underlying the RS4yr model, there is a one in four chance (25% probability) the Weaver Sockeye return will be below 23,000 (3.9 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 96,000 (16.0 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 47,000 (7.9 age-4 R/EFS) is well below the average return on this cycle (345,000) (Tables 1 and 2). The five year old component of the 2012 return is expected to contribute 89% of the total forecasted return (at the 50% probability level) (Table 3).

Birkenhead

The 2008 brood year escapement for Birkenhead (6,800 EFS) was one fifth the cycle average (36,000 EFS) from 1948-2004 (Table 1, column C). This escapement estimate is likely biased low as high waters delayed fence installation by one week in 2008. Spawning success in 2008 was 66%, compared to a long-term average of 92%. Four year old productivity in recent years (1998-2005 average: 1.6 R/EFS) has been relatively low compared to the early time-series (brood years 1948-1979 average: 9.4 R/EFS), and the long-term average (1948-2005 average: 5.6 R/EFS) for this stock (Table 2, columns B and D).

For Birkenhead, the top ranked models are the KF, Ricker (Ei), RAC (tied third), and Ricker (tied third) (Table 5). For each individual performance measure, only the KF model ranked within the top 50% (10 out of 20) of all models compared for this stock (Table 5). Forecasts produced by the top ranked models were not similar, varying by 68% (Table 6). The KF model generated the lowest forecast, reflecting the recent decline in productivity for this stock. The KF model was used for the 2012 Birkenhead forecast, as it ranked first on average across performance measures, and it ranked high on each individual performance measure (Table 5). Given the assumptions underlying the KF model, there is a one in four chance (25% probability) the Birkenhead Sockeye return will be below 45,000 (1.2 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 155,000 (6.0 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 85,000 (2.7 age-4 R/EFS) is well below the average return on this cycle (281,000) (Tables 1 and 2). The five year old component of the 2012 return is expected to contribute 79% of the total forecasted return (at the 50% probability level) (Table 3).

4 ENVIRONMENTAL CONDITIONS

Understanding the mechanisms that effect Fraser Sockeye survival is complex, given their broad distribution in both the freshwater and marine environment throughout their life-history (typically two years in freshwater followed by two years in the marine environment). For most Fraser Sockeye populations with juvenile abundance data, which can be used to partition early freshwater survival and late freshwater survival/marine survival, survival trends in recent years are more closely associated with marine (and late freshwater) survival than early freshwater survival (Peterman and Dorner 2011). It is typically thought that early marine survival most strongly influences salmonid survival (Beamish and Mahnken 2001). Therefore, for Fraser Sockeye, marine conditions in 2010 would generally be expected to most strongly influence return abundances in 2012. Although leading indicators for Fraser Sockeye survival are a work in progress, information on ocean conditions in the 2010 Fraser Sockeye smolt outmigration year and preliminary work on indicators are presented below.

In 2010, Pacific Ocean conditions shifted from El Niño (warmer ocean waters along the coast) early in the year to La Niña (cooler coastal ocean waters) later in the year (Crawford and Irvine 2011). The Strait of Georgia, where Fraser Sockeye first enter the marine environment, shifted from cool to normal/warm in 2010 (Crawford and Irvine 2011). Warmer ocean conditions are generally thought to reduce B.C. and Washington salmon population's survival, while cooler conditions are thought to improve B.C. and Washington salmon survival (Mueter et al. 2002). Therefore, 2010 ocean temperatures indicate mixed signals for ocean survival for most Fraser Sockeye returning in 2012.

At the base of the food web, phytoplankton abundance (as measured as chlorophyll concentrations in the ocean) was slightly lower in the Strait of Georgia in 2010, and the chlorophyll bloom occurred later (mid-April) compared to most other years (March to early-April). Zooplankton, small animals that drift in ocean currents, provide a food source for juvenile fish species including salmon. Off the coast of Oregon, cold-water zooplankton (higher lipid content) biomass was high (typical of cool water conditions), in contrast however, zooplankton diversity was also high (typical of warm water conditions) (Crawford and Irvine 2011). In the Strait of Georgia, where Fraser Sockeye first enter the ocean, large and medium sized copepod biomass increased from previous low biomass years (from 2000 to 2008) (Crawford and Irvine 2011). At higher levels of the food web, Triangle Island Cassin auklet chick growth rates were extremely low in 2010, linked to the late arrival of spring weather. Coast wide, herring adult biomass was generally low in all areas except the Strait of Georgia, where the stock remains somewhat high due to its near-record biomass several years ago (Crawford and Irvine 2011). In recent years, Strait of Georgia herring biomass and Chilko marine survival have been correlated (R^2=0.4) (J. Schweigert, DFO, pers. comm.). Herring biomass in 2010 was average (relative to the 1996-2010 herring time series). Therefore, Chilko marine survival, as predicted by herring biomass in 2010 would be average compared to the short-term Chilko marine survival time series (average ~4%) but below the long-term average (~9%).

5 DISCUSSION

Unlike the 2010 and 2011 forecasts (Grant et al. 2010; Grant and MacDonald 2012), the 2012 forecast does not present alternative scenarios of future survival. Instead, a single forecast scenario is presented. In the 2012 forecast scenario, the suite of appropriate candidate models, including both long-term productivity (RAC, TSA, MRS, RSC, power, Ricker, Ricker-cyc, Ricker-environmental covariate, power-environmental covariate, and Larkin) and recent productivity (R1C, R2C, RS1, RS2, RS4yr, RS8yr, and KF) models, was evaluated for each stock across the entire time-series (Table 4). In contrast, in past year's (2010 and 2011) forecasts the 'Recent Productivity' scenario evaluated the relative performance of recent productivity models only, and the 'Long-Term Average Productivity' scenario evaluated the relative performance of only long-

term average models. For the 2012 forecast, the resulting model composition, therefore, includes a mixture of models that consider both recent and long-term periods of productivity, evaluated over the full stock-recruitment time series.

The low productivity exhibited by most Fraser Sockeye stocks in recent years (brood years 1997 – 2004) has caused returns to fall at the low end of their forecast distributions for many stocks. Although returns in 2010 and 2011 were larger, due to increased productivity in those years, it is unclear whether this recent improvement in productivity will persist through to the 2012 return year. Given this uncertainty in survival through to 2012 returns, a sensitivity analysis was conducted as part of the 2012 forecast process, to explore model performance over the recent (generally low productivity) stock-recruitment time series. Specifically, the analysis was conducted to evaluate whether recent productivity models (which emphasize the low productivity period prior to the 2010 return year) perform better than models that consider long-term average productivity, when evaluated over the recent (low productivity) period (Appendix 1). The 2012 'Recent Model Performance' sensitivity analysis differs from scenarios presented in previous years in that this analysis evaluated the performance of all candidate models over the recent period; it did not evaluate only recent productivity models. Apart from the time period used for model evaluation, the sensitivity analysis used identical methods to the 2012 forecast.

Despite differences in productivity between the recent (generally low) stock-recruitment time series and the long-term time series, the sensitivity analysis ('Recent Model Performance') forecast was similar to the 2012 forecast (i.e. 21% difference between these forecasts at the 50% probability level). The first factor contributing to this similarity is the evaluation of an identical suite of models for each stock in both the sensitivity analysis and 2012 forecasts. In previous years, partitioning recent versus long-term productivity models between scenarios resulted in larger percent differences between the scenario forecasts. Another possible factor that may contribute to the similarity between these forecasts is a potential issue regarding how model performance for the recent productivity Kalman Filter (KF) Ricker model is evaluated with the new jackknife CV approach. Since jackknife analysis uses the entire stock-recruitment time series (minus the forecast year) for model calibration, data that fall both before and after the forecast year are used to predict returns. This is a particular issue for the time-varying KF Ricker model, given it has both past and future time-varying productivity data to predict returns in the jackknife CV process. Therefore, jackknife CV approaches may produce an overly optimistic evaluation of this model. Other models that emphasize recent productivity use previous returns or productivity in their estimation, and therefore, do not suffer from the same issue as the KF Ricker model

The model selection process also contributes to the similarities between sensitivity analysis and 2012 forecasts. Specifically, given the very low brood year escapements for most stocks in 2008, the model selection process resulted in the use of biological models in cases where non-parametric models, which do not use brood year abundance data as predictor variables, ranked first. In a few cases, this model selection criterion led to the same model choice in both the sensitivity analysis and 2012 forecasts, despite it not being first ranked in one of the two scenarios. In addition, for those stocks with low brood year escapements, biological models and non-parametric models that use brood year escapement as a predictor variable all produced similar low forecasts. Therefore, even where different model forms were used between scenarios, overall forecasts for most stocks were relatively close. Given the similarities between the sensitivity analysis and 2012 forecasts, the 'Recent Model Performance' analysis provides further support for the models and forecasts produced by the 2012 forecast process.

Depending on the stock, either recent or long-term productivity models were used to generate the 2012 forecast. For biological models, the forecast distribution represents the range of returns expected based on past observations, from the low end of past productivity (10% probability level forecast) to the high end (90% probability level). For non-parametric models, the distribution represents that model's performance over the entire stock-recruitment time

series of historical productivity. Recent productivity biological and non-parametric models tend to produce narrower distributions centered on lower abundances than long-term average productivity models. Therefore, it is important to consider which model type is being used when evaluating a stock's 2012 returns relative to its forecast distribution.

The key difference between the 2012 forecast methods and those of previous years, is the use of jack-knife cross-validation (CV) analysis to evaluate model performance. The jackknife approach was adopted for the 2012 forecast instead of the previously used retrospective (CV) approach for a number of reasons. Jackknife analysis uses a larger calibration sample size than retrospective analysis; jackknife analysis uses the full time series of stock recruitment data, excluding only the year being forecast. Coincidently, the jackknife calibration samples more appropriately reflect the characteristics of the validation data. In contrast, retrospective analysis calibration sample sizes ranges from half of to equal to the jackknife sample size, because for each validation year, only previous year's stock-recruitment data are used to calibrate the models. Smaller sample sizes can result in underestimates of model performance (Steyerberg et al. 2001) and can also produce poor assessments of prediction accuracy (McCuen 2005; Steyerberg et al. 2001). Therefore, since retrospective analysis calibration sample sizes are small for forecasts that fall early in the validation time series, relative to later years, evaluations of model performance may be confounded by changes in the calibration sample. Further, since the calibration sample is largely comprised of the first half of the time series, sequentially including an additional year of calibration data for each step through the validation time series, the characteristics of the calibration sample may vary from the validation sample (McCuen 2005). For Fraser Sockeye stocks, given that most stocks have exhibited systematic declines in productivity starting as early as the 1950's, weighting the calibration sample more heavily on the earlier, more productive half of the time series would result in different productivity characteristics to the validation sample (the second half of the time series).

The jackknife approach has several additional advantages over retrospective analysis. First, the models evaluated using jack-knife analysis most closely reflect those used for the 2012 forecast, in that they are calibrated using all of the available data. In contrast, retrospective analysis uses different data to fit the models in each year of the validation period, altering the model as additional years are added to the time-series (in particular, for RAC, TSA, and biological models). Data used by the remaining non-parametric models, which are based on returns (R1C, R2C) or productivity (RS1, RS2, RS4yr, RS8yr) from previous years, are largely similar in the jackknife and retrospective approaches (i.e. stock-recruitment data used for these forecasts are identical, however data used to estimate the forecast probability distributions vary). An additional benefit of jack-knife analysis is that it provides the flexibility to explore different approaches in the model evaluation process. For example, model performance can be compared across years (wherever they may occur in the time series) with similar productivity, similar brood year escapements, etc. Retrospective analysis results do not provide similar flexibility. Some preliminary work has been done to compare model performance for years with similar (low) brood year escapements to 2008 (for the 2012 forecast). This will be explored in more detail for the 2013 forecasts, given that 2009 brood year escapements were particularly low.

Performance measures from the retrospective analyses completed in previous years (See Appendix 1 in Grant and MacDonald 2011) are not directly comparable to the 2012 jackknife results, given differences in both the data used for model calibration, and the length of the model validation period, between the two CV approaches. It is challenging to draw conclusions simply from the variation in performance measure values and model ranks between the two CV approaches. Simulation modeling is one approach that might provide valid comparisons between the two CV approaches (McCuen 2005).

6 RECOMMENDATIONS

- In attempts to improve the predictability of Fraser Sockeye survival, return forecasts have incorporated environmental variables, both quantitatively into forecast models (Grant et al. 2010; Grant and MacDonald 2012), and qualitatively into forecast advice (DFO 2009). However, to date, the inclusion of environmental variables has not significantly decreased forecast uncertainty (i.e. it has not significantly explained annual survival rates). Future Fraser Sockeye forecast work should involve research and workshops that explore environmental variables that could be used to explain inter-annual variability in Fraser Sockeye recruitment. Until leading indicators are developed to reduce Fraser Sockeye forecast uncertainty, future forecasts should rely on methods described in the current paper.
- The Ricker-cyc model should be considered for removal from the suite of candidate models, due to potential time-series bias that may arise from the shortened dataset used by this model.
- Further work on the KF Ricker model form is recommended. Performance of the KF Ricker model is potentially inappropriately evaluated when using the jackknife CV approach. Since this model estimates time-varying productivity over the time-series, calibrating this model with the full stock-recruitment time series, which includes data that fall both before and after the forecast year, may lead to overly optimistic estimates of performance. Further, Larkin derived Kalman Filter models may be more appropriate for highly cyclic stocks, since the Larkin model takes into consideration cycle line density-dependent interactions.
- Future work on the forecast R-code is highly recommended. The addition of new approaches and modifications each year has left the existing code in need of an overhaul. Also, advances in the available statistical packages could stream-line the existing code considerably. This will require resources outside of the existing program, as sufficient resources are currently not available.
- For future forecasts, particularly 2013, for which the brood year (2009) EFS abundances were anomalously low for most Fraser Sockeye stocks, alternate scenarios could compare model performance for years with similar brood year escapements, specific productivity regimes, etc.

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Table 1. Fraser Sockeye forecasts for 2012 are presented by stock and timing group from the 10% to 90% probability levels (columns A and J to N). The selected models for each stock are presented in column B. Average run sizes are presented across all cycles (H) and for the 2012 cycle (I). Brood year escapements (smolts for Chilko and Cultus) for four (2008) and five year old (2007) recruits returning in 2012 (columns C and D) are presented and colour coded relative to their cycle average from 1948-2004 (brood year). Forecasted returns (column G), corresponding to the 50% probability level (column L), and geometric average four year old productivities $\log_e$(R/EFS) associated with returns from the last eight (1998-2005) (column E) and four brood years (2002-2005) (column F) are also colour coded relative to their cycle average. Color codes represent the following: red (< average), yellow (average) and green (> average).

A	B	C	D	E	F	G	H	I	J	K	L	M	N
Run timing group		BY (08)	BY (07)	Prod.	Prod.	Ret	Mean Run Size		Probability that Return will be at or Below Specified Run Size[a]				
Stocks	Forecast Model[b]	(EFS)	(EFS)	(-8yr)	(-4yr)	2012	all cycles[c]	2012 cycle[d]	10%	25%	50%	75%	90%
Early Stuart	Ricker (EI)	14,400	2,400	3.2	3.0		311,000	130,000	38,000	61,000	86,000	181,000	279,000
Early Summer							910,000	617,000	109,000	190,000	309,000	660,000	1,214,000
(total excluding miscellaneous)							616,000	617,000	62,000	103,000	194,000	360,000	656,000
Bowron	KF	300	1,100	4.6	4.7		39,000	27,000	1,000	1,000	2,000	4,000	6,000
Fennell	Power	200	6,800	7.1	6.2		25,000	34,000	5,000	7,000	12,000	20,000	32,000
Gates	KF	1,800	1,100	8.4	5.6		53,000	136,000	4,000	6,000	12,000	21,000	38,000
Nadina	MRJ	10,300	1,000	4.9	6.3		80,000	137,000	17,000	33,000	70,000	147,000	280,000
Pitt	KF	5,400	19,800	2.5	0.9		72,000	81,000	11,000	18,000	38,000	65,000	110,000
Raft	Ricker (PDO)	3,800	8,100	7.5	8.9		32,000	57,000	22,000	34,000	56,000	88,000	136,000
Scotch	Larkin	100	4,800	10.6	6.5		78,000	12,000	100	200	300	700	1,400
Seymour	Ricker-cyc	300	5,900	6.3	5.6		131,000	34,000	2,000	4,000	8,000	16,000	38,000
Misc[e]	RS (Sc/Se)	500	3,800				NA	NA	1,000	3,000	6,000	10,000	17,000
Misc[f]	RS (Ra/Fe)	200	1,000				NA	NA	1,000	2,000	3,000	6,000	13,000
Misc[g]	RS (Ra/Fe)	1,000	9,800				NA	NA	6,000	14,000	24,000	48,000	69,000
Misc[h]	RS (Esum)	19,700	1,100				NA	NA	36,000	70,000	127,000	230,000	431,000
Misc[i]	RS (Esum)	150	2,000				NA	NA	1,000	3,000	5,000	6,000	18,000
Summer							3,730,000	2,501,000	529,000	839,000	1,420,000	2,440,000	4,166,000
Chilko[j]	KF(juv)	11.9 M	25.2 M	0.06	0.05		1,380,000	1,790,000	228,000	342,000	582,000	949,000	1,274,000
Late Stuart	Power	57,800	4,100	3.7	3.8		980,000	107,000	82,000	166,000	336,000	730,000	1,550,000
Quesnel	R1C	2,500	55,800	1.7	1.9		1,398,000	57,000	17,000	33,000	67,000	137,000	281,000
Stellako	R2C	73,600	19,000	3.1	1.8		462,000	467,000	181,000	287,000	453,000	714,000	1,075,000
Late							3,099,000	711,000	86,000	119,000	341,000	496,000	880,000
(total excluding miscellaneous)							3,099,000	711,000	62,000	112,000	336,000	486,000	840,000
Cultus[j & k]	KF(juv)	145,300	341,000	0.02	0.02		38,000	21,000	1,000	1,000	3,000	7,000	15,000
Harrison[l]	KF	4,400	100,800	32.9	43.2		60,000	19,000	20,000	38,000	83,000	104,000	401,000
Late Shuswap	Ricker-cyc	60	32,500	4.6	0.7		2,102,000	29,000	1,000	3,000	8,000	19,000	46,000
Portage	Larkin	60	800	6.3	3.9		40,000	16,000	500	1,000	2,000	4,000	8,000
Weaver	RS4yr	600	15,800	10.8	5.7		363,000	346,000	12,000	23,000	47,000	98,000	181,000
Birkenhead	KF	6,800	54,300	4.7	2.6		390,000	281,000	27,000	46,000	86,000	156,000	290,000
Misc. non-Shuswap[m]	RS (Birkenhead)	600	2,600				NA	NA	4,000	7,000	13,000	23,000	40,000
TOTAL SOCKEYE SALMON							-	-	743,000	1,263,000	2,118,000	3,760,000	6,604,000
(TOTAL excluding miscellaneous)							(7,071,000)	(3,848,000)	(680,000)	(1,104,000)	(1,841,000)	(3,427,000)	(6,019,000)

a. Probability that return will be at, or below, specified projection.
b. See Table 4 for model descriptions
c. Sockeye: 1953-2009 (depending on start of time series)
d. Sockeye: 1956-2008 (depending on start of time series)
e. Unforecasted miscellaneous Early Summer Stocks (Early Shuswap stocks: S.Thompson; used Scotch/Seymour R/EFS)
f. Unforecasted miscellaneous Early Summer stocks (N. Thomson tributaries; used Raft/Fennell R/EFS).
g. North Thompson River (used Raft/Fennell R/EFS)
h. Chilliwack Lake and Dolly Varden Creek (used Early Summer R/EFS)
i. Nahatlach River & Lake (used Early Summer R/EFS)
j. Brood year smolts in columns C & D (not effective females)
k. For Cultus, this 'Long-Term Average Productivity' smolt-jack forecast uses the full marine survival time series.
l. Harrison are age-4 (column C) and age-3 (column D).
m. Unforecasted miscellaneous Late Run stocks (Harrison Lake down stream migrants including Big Silver, Cogburn, etc.); used Birkenhead R/EFS & Weaver age proportions

Definitions: BY: Brood year; BY08: brood year 2008; BY07: brood year 2007; EFS: effective female spawners; Prod. (8yr), Prod. (4yr): Productivity in age-4 recruits-per-effective female spawners in the last 8 yrs (1998-2005) or last 4 yrs (2001-2005); EI (Entrance Island sea-surface-temperature); PDO (Pacific Decadal Oscillation).

Table 2. For each of the 19 forecasted stocks (column A), geometric average four year old productivities loge(R/EFS) are presented for the first part of the time series (up to and including 1979) (column B), the latter part of the time-series, which is used as a reference period (1980-2005) (column C), and the most recent eight (1998-2005) (column D), and four brood years (2002-2005) (column E), for comparison. Four year old productivities associated with the various probability levels of the 2012 forecast (based on Table 1 forecasts and escapements) are presented in columns (F) to (J). Forecast productivities are presented as R/EFS, but the loge (R/EFS) was used to determine colour codes for columns (B) to (E) (see methods in Grant et al. 2010). Colour codes represent the following: Red (< average), yellow (average) and green (>average).

A	B	C	D	E	F	G	H	I	J
Run timing group / Stocks	Early Time Series Avg R/EFS (up to 1979)	Reference Period Avg R/EFS (1980-2005)	Last 8 yrs Avg R/EFS (1998-2005)	Last 4 yrs Avg R/EFS (2002-2005)	"Long-Term Average" 2012 forecast productivities (R/EFS) for each probability level in Table 1 by stock 10%	25%	50%	75%	90%
Early Stuart	9.5	3.9	2.5	2.1	2.6	4.1	6.7	11.0	18.6
Early Summer									
Bowron	9.0	4.8	2.8	2.3	1.5	2.2	4.4	7.3	12.7
Fennell	20.0	4.1	4.0	3.2	6.2	10.5	19.0	34.8	57.1
Gates	17.0	7.3	4.5	3.1	1.7	3.1	6.0	11.0	19.3
Nadina	10.1	5.3	3.0	3.5	1.6	3.2	6.7	14.2	27.7
Pitt	2.6	0.6	0.3	0.1	0.1	0.2	0.6	1.4	2.5
Raft	7.9	4.5	2.7	2.0	1.6	2.8	5.2	9.2	16.4
Scotch		6.7	6.7	3.5	0.5	0.9	1.9	4.0	8.6
Seymour	10.9	5.1	5.4	3.6	2.5	3.9	7.4	13.0	23.5
Summer									
Chilko[a]	0.08	0.06	0.02	0.02	0.01	0.02	0.04	0.06	0.10
Late Stuart	11.3	7.3	2.6	2.1	1.4	2.6	5.6	12.4	26.5
Quesnel[b]	10.2	4.8	1.0	1.0	1.6	3.1	6.3	12.9	24.6
Stellako	10.1	4.5	1.5	0.7	2.3	3.5	5.4	8.6	12.9
Late									
Cultus[a]	0.05	0.04	0.02	0.02	0.00	0.01	0.02	0.05	0.10
Harrison	2.3	4.9	6.3	3.4	1.1	3.4	8.9	23.4	55.2
Late Shuswap[b]	5.9	4.0	2.4	0.7	0.0	0.0	1.2	4.8	14.5
Portage	20.9	8.8	3.5	2.2	4.8	7.9	19.0	41.3	96.3
Weaver	15.2	10.2	8.8	3.9	2.1	3.9	7.9	16.0	30.3
Birkenhead	9.4	3.0	1.6	0.9	0.6	1.2	2.7	6.0	11.9

a. Chilko and Cultus are marine survival (recruits per smolt).
b. Quesnel and Late Shuswap are cycle averages.

Table 3. Age composition of forecasted returns for each stock at the 50% probability level.

Sockeye stock/timing group	2012 Fraser Sockeye Forecasts				
	Model	FOUR YEAR OLDS 50%[a]	FIVE YEAR OLDS 50%[a]	TOTAL 50%[a]	Age-4 Proportion
Early Stuart	*Ricker (Ei)*	**97,000**	**2,000**	**99,000**	**98%**
Early Summer		**246,750**	**112,550**	**359,300**	
Bowron	*KF*	1,000	1,000	2,000	**50%**
Fennell	*Power*	4,000	8,000	12,000	**33%**
Gates	*KF*	11,000	1,000	12,000	**92%**
Nadina	*MRJ*	68,000	2,000	70,000	**97%**
Pitt	*KF*	3,000	32,000	35,000	**9%**
Raft	*Ricker (PDO)*	19,000	36,000	55,000	**35%**
Scotch	*Larkin*	250	50	300	**83%**
Seymour	*Ricker -cyc*	2,000	6,000	8,000	**25%**
Misc [e]	*RS*	4,000	2,000	6,000	**56%**
Misc [f]	*RS*	1,500	1,500	3,000	**50%**
Misc [g]	*RS*	7,000	17,000	24,000	**29%**
Misc [h]	*RS*	125,000	2,000	127,000	**98%**
Misc [i]	*RS*	1,000	4,000	5,000	**20%**
Summer		**1,181,000**	**239,000**	**1,420,000**	
Chilko	*KF (juv)*	441,000	121,000	562,000	**78%**
Late Stuart	*Power*	322,000	16,000	338,000	**95%**
Quesnel[b]	*R1C*	16,000	51,000	67,000	**24%**
Stellako[b]	*R2C*	402,000	51,000	453,000	**89%**
Late		**72,300**	**168,900**	**241,000**	
Cultus	*KF (juv)*	3,000	100	3,000	**100%**
Harrison[c]	*KF*	39,000	44,000	83,000	**47%**
Late Shuswap	*Ricker-cyc*	100	8,000	8,000	**1%**
Portage	*Larkin*	1,200	800	2,000	**60%**
Weaver	*RS4yr*	5,000	42,000	47,000	**11%**
Birkenhead	*KF*	18,000	67,000	85,000	**21%**
Misc. non-Shuswap[l]	*RS*	6,000	7,000	13,000	**46%**
Total		**1,597,050**	**522,450**	**2,119,300**	**75%**

a. Probability that actual return will be at or below specified run size
b. Age compositions for Quesnel and Stellako are calculated using the proportions that would be applied by a biolo
c. Harrison are age-4 (in four year old columns) and age-3 (in five year old columns) forecasts

Below subscripts line up with same subscripts in Tables 1 & 2

e. Unforecasted mis. Early Summer Stocks (Early Shuwap stocks: S.Thompson); return timing most similar to Sco
f. Unforecasted misc. Early Summer stocks (N. Thomson tributaries; return timing most similar to Raft/Fennell (Ra
g. North Thompson River
h. Chilliwack Lake and Dolly Varden Creek (Esum)
i. Nahatlach River & Lake (Esum)
l. Unforecasted miscellaneous Late Run stocks (Harrison L.)

Table 4. List of candidate models organized by their two broad categories (non-parametric and biological) with descriptions. Models that emphasize recent stock productivity are indicated. Models are described in detail in Appendices 1 to 3 of Grant et al. (2010). Where applicable, models use effective female spawner data (EFS) as a predictor variable unless otherwise indicated by '(juv)' or '(smolt)' next to the model (Table 2), where fry data or smolt data are used instead.

MODEL		DESCRIPTION
A. Non-Parametric Models		
R1C	(recent productivity)	Return from 4 years previous
R2C	(recent productivity)	Average return from 4 & 8 years previous
RAC		Average return of the cycle line over the time series
TSA		Average return across all cycles lines over the time series
RS1	(recent productivity)	Product of productivity from 4 years previous (one cycle) and brood year EFS (or juv/smolt)
RS2	(recent productivity)	Product of average productivity from 4 & 8 years previous (two cycles) and brood year EFS (or juv/smolt)
RS4yr	(recent productivity)	Product of average productivity over the last 4 years and brood year EFS (or juv/smolt)
RS8yr	(recent productivity)	Product of average productivity over the last 8 years and brood year EFS (or juv/smolt)
MRS		Product of average productivity from entire time series and brood year EFS (or juv/smolt)
RSC		Product of average cycle-line productivity (entire time-series) and brood year EFS (or juv/smolt)
RS		Product of average productivity (entire time-series) for index stocks and brood year EFS (or juv/smolt) (used for miscellaneous stocks)
B. Biological Models		
power		Bayesian
Ricker		Bayesian
Ricker-cyc		Bayesian (cycle line data only)
Larkin		Bayesian
KF Ricker	(recent productivity)	Bayesian
smolt-jack		Bayesian
Covariates for Biological Models		
FrD-mean		Mean Fraser discharge (April - June)
Ei		Entrance Island sea-surface temperature (April – June)
Pi		Pine Island sea-surface temperature (April – July)
FrD-peak		Peak Fraser Discharge
PDO		Pacific Decadal Oscillation

Table 5. Performance measure calculations and rankings for the 2012 forecast. For each stock, performance measures were calculated by model using the full jack-knife forecast time-series. Model ranking by performance measure, and average rank across all four performance measures are presented. The last column for each stock indicates whether the model consistently ranks within the top half of all models evaluated on every performance measure.

RUN-TIMING: EARLY STUART

Early Stuart	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	-0.017	0.288	-3.239	0.406	7	20	21	18	16.5	17	NO
R1C	-0.025	0.209	-0.638	0.367	11	15	15	16	14.25	14	NO
R2C	-0.03	0.241	-1.021	0.363	13	17	18	15	15.75	16	NO
RAC	-0.007	0.202	-1.333	0.297	5	14	19	13	12.75	12	NO
MRS	-0.026	0.176	-0.467	0.272	12	8	6	6	8	7	NO
RS1	-0.17	0.262	-0.678	0.512	21	18	16	19	18.5	19	NO
RS2	-0.166	0.268	-0.713	0.568	20	19	17	20	19	20	NO
RSC	-0.041	0.189	-0.533	0.295	15	12	12	12	12.75	12	NO
RS4yr	-0.107	0.201	-0.534	0.345	18	13	13	14	14.5	15	NO
RS8yr	-0.113	0.219	-0.614	0.398	19	16	14	17	16.5	17	NO
Ricker	0.001	0.16	-0.498	0.25	1	4	10	4	4.75	3	YES
Ricker (FrD-mean)	0.003	0.183	-0.515	0.277	3	11	11	9	8.5	8	NO
Ricker (EI)	0.022	0.144	-0.347	0.235	9	2	3	1	3.75	1	YES
Ricker (PI)	0.022	0.148	-0.278	0.246	9	3	1	2	3.75	1	YES
Ricker (FrD-peak)	0.013	0.177	-0.487	0.276	6	9	8	8	7.75	6	YES
Ricker (PDO)	0.003	0.16	-0.471	0.261	3	4	7	5	4.75	3	YES
Ricker cyc	0.019	0.18	-0.49	0.28	8	10	9	10	9.25	10	YES
Power	0.059	0.166	-0.4	0.273	17	6	4	7	8.5	8	NO
Larkin	0.041	0.17	-0.413	0.281	15	7	5	11	9.5	11	NO
KF	0.035	0.143	-0.279	0.248	14	1	2	3	5	5	NO

RUN-TIMING: EARLY SUMMER

Bowron	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	-0.006	0.031	-1.815	0.045	15	19	21	19	18.5	18	NO
R1C	-0.004	0.021	-0.86	0.035	10	2	14	3	7.25	7	NO
R2C	-0.006	0.024	-0.971	0.035	15	8	16	3	10.5	14	NO
RAC	-0.006	0.026	-1.56	0.039	15	15	20	13	15.75	15	NO
MRS	-0.001	0.022	-0.692	0.034	2	3	5	2	3	2	YES
RS1	-0.02	0.037	-1.222	0.061	21	20	19	20	20	20	NO
RS2	-0.011	0.028	-1.045	0.044	20	18	18	18	18.5	18	NO
RSC	0.001	0.024	-0.715	0.037	2	8	7	7	6	5	YES
RS4yr	-0.01	0.026	-0.813	0.043	19	15	13	17	16	16	NO
RS8yr	-0.008	0.026	-0.806	0.04	18	15	15	16	16	16	NO
Ricker	0.006	0.023	-0.747	0.039	13	5	8	13	9.75	12	NO
Ricker (FrD-mean)	0.001	0.025	-0.761	0.038	2	11	10	10	8.25	9	NO
Ricker (EI)	0.003	0.023	-0.686	0.036	8	5	3	6	5.5	4	YES
Ricker (PI)	0.004	0.022	-0.589	0.035	10	3	2	3	4.5	3	YES
Ricker (FrD-peak)	0.001	0.025	-0.787	0.036	2	11	12	10	8.75	10	NO
Ricker (PDO)	0.002	0.024	-0.686	0.037	7	8	4	7	6.5	6	YES
Ricker cyc	0.001	0.025	-0.779	0.037	2	11	11	7	7.75	8	NO
Power	0.006	0.023	-0.747	0.039	13	5	8	13	9.75	12	NO
Larkin	0.004	0.025	-0.71	0.038	10	11	6	10	9.25	11	NO
KF	0.003	0.02	-0.532	0.032	8	1	1	1	2.75	1	YES

Fennell	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	0.003	0.017	-0.655	0.02	5	3	6	1	3.75	5	YES
R1C	0.001	0.022	-0.6	0.028	1	14	4	14	8.25	9	NO
R2C	0.002	0.018	-0.384	0.023	4	6	1	8	4.75	6	YES
RAC	0.003	0.016	-0.49	0.02	5	1	2	1	2.25	2	YES
MRS	-0.021	0.029	-1.576	0.04	16	15	16	15	15.5	15	NO
RS1	-0.022	0.04	-2.193	0.055	18	20	20	19	19.25	19	NO
RS2	-0.023	0.038	-2.108	0.06	19	19	19	20	19.25	19	NO
RSC	-0.024	0.031	-1.795	0.043	20	16	18	16	17.5	18	NO
RS4yr	-0.015	0.031	-1.265	0.046	15	16	15	17	15.75	16	NO
RS8yr	-0.021	0.033	-1.73	0.05	16	18	17	18	17.25	17	NO
Ricker	-0.003	0.016	-0.709	0.02	5	1	7	1	3.5	3	YES
Ricker (FrD-mean)	-0.007	0.018	-0.908	0.022	9	6	9	6	7.5	7	YES
Ricker (EI)	-0.007	0.019	-0.936	0.022	9	10	10	6	8.75	10	YES
Ricker (PI)	-0.005	0.018	-0.845	0.023	8	6	8	8	7.5	7	YES
Ricker (FrD-peak)	-0.012	0.02	-1.158	0.024	14	11	14	11	12.5	13	NO
Ricker (PDO)	-0.007	0.021	-0.984	0.024	9	13	12	11	11.25	12	NO
Ricker cyc	-0.01	0.02	-1.084	0.027	13	11	13	13	12.5	13	NO
Power	0.001	0.017	-0.538	0.02	1	3	3	1	2	1	YES
Larkin	-0.008	0.018	-0.946	0.023	12	6	11	8	9.25	11	NO
KF	-0.001	0.017	-0.633	0.021	1	3	5	5	3.5	3	YES

Gates	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	0.01	0.049	-1.447	0.073	6	18	19	18	15.25	17	NO
R1C	0	0.038	-0.585	0.062	1	7	3	16	6.75	6	NO
R2C	0	0.035	-0.524	0.059	1	4	2	15	5.5	3	NO
RAC	0.006	0.034	-0.333	0.054	5	2	1	8	4	2	YES
MRS	-0.011	0.036	-1.139	0.049	10	5	10	1	6.5	4	YES
RS1	-0.029	0.055	-1.953	0.119	20	20	20	20	20	20	NO
RS2	-0.022	0.051	-1.287	0.073	19	19	16	18	18	19	NO
RSC	-0.015	0.039	-1.246	0.055	17	10	13	10	12.5	15	NO
RS4yr	-0.01	0.04	-0.885	0.058	6	14	7	14	10.25	12	NO
RS8yr	-0.016	0.043	-1.095	0.066	18	17	9	17	15.25	17	NO
Ricker	-0.012	0.037	-1.268	0.049	16	6	15	1	9.5	10	NO
Ricker (FrD-mean)	-0.011	0.04	-1.355	0.054	10	14	18	8	12.5	15	NO
Ricker (EI)	-0.011	0.039	-1.227	0.051	10	10	11	3	8.5	9	NO
Ricker (PI)	-0.01	0.038	-1.242	0.051	6	7	12	3	7	7	NO
Ricker (FrD-peak)	-0.01	0.04	-1.323	0.053	6	14	17	7	11	14	NO
Ricker (PDO)	-0.011	0.039	-1.25	0.052	10	10	14	5	9.75	11	NO
Ricker cyc	-0.011	0.039	-0.962	0.057	10	10	8	13	10.25	12	NO
Power	0.011	0.033	-0.755	0.056	10	1	5	12	7	7	NO
Larkin	-0.001	0.038	-0.871	0.055	3	7	6	10	6.5	4	YES
KF	0.005	0.034	-0.744	0.052	4	2	4	5	3.75	1	YES

Nadina	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	0.01	0.089	-2.6	0.106	16	25	33	23	24.25	27	NO
R1C	0.003	0.056	-0.547	0.105	3	5	16	22	11.5	10	NO
R2C	0.006	0.057	-0.94	0.099	6	9	28	10	13.25	12	NO
RAC	0.006	0.066	-2.097	0.103	6	20	32	16	18.5	25	NO
MRS	0.007	0.062	-0.471	0.104	10	16	10	19	13.75	13	NO
RS1	-0.095	0.135	-1.117	0.326	32	32	31	32	31.75	32	NO
RS2	-0.101	0.14	-1.029	0.396	33	33	30	33	32.25	33	NO
RSC	-0.019	0.079	-0.532	0.161	26	29	14	29	24.5	28	NO
RS4yr	0.003	0.07	-0.694	0.113	3	26	25	25	19.75	26	NO
RS8yr	0	0.063	-0.596	0.103	1	18	21	16	14	15	NO
Ricker	0.008	0.062	-0.534	0.102	13	16	15	15	14.75	16	YES
Ricker (FrD-mean)	0.009	0.059	-0.527	0.099	14	12	12	10	12	11	YES
Ricker (EI)	0.01	0.061	-0.564	0.101	16	14	18	13	15.25	17	NO
Ricker (PI)	0.007	0.063	-0.594	0.104	10	18	20	19	16.75	21	NO
Ricker (FrD-peak)	0.013	0.054	-0.529	0.088	19	3	13	1	9	2	NO
Ricker (PDO)	0.009	0.061	-0.564	0.099	14	14	17	10	13.75	13	NO
Ricker cyc	-0.016	0.077	-0.613	0.143	22	28	22	28	25	29	NO
Power	0.006	0.066	-0.587	0.109	6	20	19	24	17.25	22	NO
Larkin	0.002	0.066	-0.69	0.124	2	20	24	26	18	23	NO
KF	0.017	0.06	-0.454	0.103	24	13	8	16	15.25	17	NO
MRJ	0.023	0.05	-0.315	0.088	28	1	1	1	7.75	1	NO
RJ1	-0.047	0.089	-0.995	0.215	31	30	29	31	30.25	31	NO
RJ2	-0.035	0.09	-0.784	0.207	30	31	26	30	29.25	30	NO
RJC	0.011	0.058	-0.368	0.095	18	11	2	8	9.75	5	NO
RJ4yr	0.008	0.066	-0.89	0.104	6	20	27	19	18	23	NO
RJ8yr	0.007	0.066	-0.637	0.101	10	20	23	13	16.5	20	NO
Power (juv)	0.015	0.057	-0.429	0.095	20	9	6	8	10.75	9	NO
Power (juv) (FrD-mean)	0.003	0.073	-0.448	0.127	3	27	7	27	16	19	NO
Power (juv) (EI)	0.015	0.056	-0.514	0.094	20	5	11	4	10	6	NO
Power (juv) (PI)	0.016	0.056	-0.468	0.094	22	5	9	4	10	6	NO
Power (juv) (FrD-peak)	0.018	0.055	-0.397	0.091	25	4	4	3	9	2	NO
Power (juv) (PDO)	0.019	0.056	-0.417	0.094	26	5	5	4	10	6	NO
KF (juv)	0.031	0.052	-0.395	0.094	29	2	3	4	9.5	4	NO

Pitt	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	-0.003	0.036	-0.794	0.045	4	2	15	2	5.75	3	NO
R1C	-0.001	0.051	-0.765	0.064	1	14	13	14	10.5	14	NO
R2C	0.001	0.045	-0.651	0.055	1	12	11	12	9	12	NO
RAC	-0.003	0.04	-0.83	0.048	4	8	16	4	8	8	NO
MRS	-0.005	0.055	-0.662	0.082	7	15	12	15	12.25	15	NO
RS1	-0.06	0.097	-1.378	0.148	20	20	19	20	19.75	20	NO
RS2	-0.042	0.077	-1.445	0.132	19	18	20	19	19	19	NO
RSC	-0.007	0.058	-0.784	0.087	11	16	14	16	14.25	16	NO
RS4yr	-0.041	0.08	-1.073	0.131	18	19	17	18	18	18	NO
RS8yr	-0.032	0.072	-1.187	0.119	17	17	18	17	17.25	17	NO
Ricker	0.008	0.04	-0.548	0.049	13	8	7	6	8.5	10	NO
Ricker (FrD-mean)	0.003	0.041	-0.572	0.052	4	11	10	11	9	12	NO
Ricker (EI)	0.007	0.039	-0.506	0.049	11	6	5	6	7	5	NO
Ricker (PI)	0.008	0.039	-0.489	0.05	13	6	3	9	7.75	6	NO
Ricker (FrD-peak)	0.005	0.04	-0.551	0.05	7	8	8	9	8	8	YES
Ricker (PDO)	0.009	0.038	-0.484	0.048	15	4	2	4	6.25	4	NO
Ricker cyc	0.001	0.045	-0.559	0.062	1	12	9	13	8.75	11	NO
Power	0.009	0.038	-0.51	0.049	15	4	6	6	7.75	6	NO
Larkin	0.006	0.036	-0.502	0.047	10	2	4	3	4.75	2	YES
KF	0.005	0.033	-0.392	0.043	7	1	1	1	2.5	1	YES

Raft	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	-0.002	0.022	-2.186	0.03	5	16	21	15	14.25	16	NO
R1C	0.001	0.017	-0.32	0.026	2	11	1	12	6.5	6	NO
R2C	0.002	0.018	-0.529	0.026	5	13	3	12	8.25	9	NO
RAC	-0.002	0.018	-1.593	0.025	5	13	20	10	12	14	NO
MRS	-0.004	0.017	-0.536	0.026	12	11	5	12	10	12	NO
RS1	-0.02	0.033	-1.156	0.052	21	21	19	20	20.25	20	NO
RS2	-0.015	0.028	-0.995	0.043	20	19	17	19	18.75	18	NO
RSC	-0.007	0.02	-0.587	0.031	17	15	6	16	13.5	15	NO
RS4yr	-0.013	0.028	-0.72	0.055	19	19	16	21	18.75	18	NO
RS8yr	-0.009	0.023	-0.675	0.042	18	17	15	18	17	17	NO
Ricker	-0.003	0.015	-0.621	0.024	11	4	8	7	7.5	8	NO
Ricker (FrD-mean)	-0.004	0.016	-0.647	0.025	12	8	12	10	10.5	13	NO
Ricker (Ei)	-0.004	0.015	-0.662	0.024	12	4	14	7	9.25	10	NO
Ricker (Pi)	-0.002	0.015	-0.602	0.023	5	4	7	4	5	4	YES
Ricker (FrD-peak)	-0.004	0.016	-0.627	0.024	12	8	10	7	9.25	10	NO
Ricker (PDO)	-0.001	0.014	-0.517	0.023	2	1	2	4	2.25	1	YES
Ricker cyc	-0.004	0.014	-0.529	0.021	12	1	4	1	4.5	2	NO
Power	0.002	0.014	-0.645	0.021	5	1	11	1	4.5	2	NO
Larkin	-0.001	0.016	-0.66	0.022	2	8	13	3	6.5	6	NO
KF	-0.002	0.015	-0.621	0.023	5	4	9	4	5.5	5	YES

Scotch	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	0	0.117	-7.6	0.182	1	20	20	20	15.25	19	NO
R1C	0.025	0.055	-1.074	0.135	11	10	13	13	11.75	14	NO
R2C	0.023	0.056	-0.811	0.135	10	11	6	13	10	9	NO
RAC	0.015	0.06	-1.044	0.134	6	14	12	12	11	12	NO
MRS	0.018	0.048	-1.153	0.097	7	5	14	4	7.5	4	NO
RS1	-0.003	0.049	-1.282	0.074	2	7	15	2	6.5	3	NO
RS2	-0.011	0.07	-1.672	0.108	4	18	18	7	11.75	14	NO
RSC	-0.036	0.045	-1.678	0.073	16	3	19	1	9.75	7	NO
RS4yr	0.036	0.068	-0.856	0.137	16	17	10	15	14.5	17	NO
RS8yr	0.025	0.075	-1.299	0.147	11	19	16	18	16	20	NO
Ricker	0.022	0.044	-0.831	0.099	9	2	8	5	6	2	YES
Ricker (FrD-mean)	0.028	0.045	-0.826	0.102	14	3	7	6	7.5	4	NO
Ricker (Ei)	0.034	0.058	-0.833	0.142	15	12	9	16	13	16	NO
Ricker (Pi)	0.048	0.061	-0.505	0.152	20	15	4	19	14.5	17	NO
Ricker (FrD-peak)	0.025	0.048	-0.913	0.112	11	5	11	8	8.75	6	NO
Ricker (PDO)	-0.019	0.059	-0.174	0.143	8	13	1	17	9.75	7	NO
Ricker cyc	-0.005	0.061	-1.478	0.114	3	15	17	9	11	12	NO
Power	0.04	0.054	-0.638	0.132	18	8	5	11	10.5	11	NO
Larkin	0.014	0.035	-0.213	0.074	5	1	2	2	2.5	1	YES
KF	0.044	0.054	-0.397	0.13	19	8	3	10	10	9	NO

Seymour	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	-0.001	0.117	-2.883	0.164	2	18	20	14	13.5	15	NO
R1C	0	0.077	-0.495	0.134	1	5	8	6	5	2	YES
R2C	-0.001	0.082	-0.488	0.14	2	8	7	10	6.75	7	YES
RAC	0.002	0.07	-0.56	0.12	5	2	11	3	5.25	4	NO
MRS	-0.002	0.084	-0.606	0.147	5	10	12	13	10	9	NO
RS1	-0.113	0.176	-1.454	0.358	20	20	19	20	19.75	20	NO
RS2	-0.078	0.145	-1.018	0.28	19	19	18	19	18.75	19	NO
RSC	-0.036	0.095	-0.702	0.2	18	14	17	17	16.5	18	NO
RS4yr	-0.023	0.1	-0.667	0.172	13	15	16	15	14.75	16	NO
RS8yr	-0.023	0.104	-0.631	0.177	13	16	15	16	15	17	NO
Ricker	0.005	0.085	-0.619	0.144	7	11	13	11	10.5	10	NO
Ricker (FrD-mean)	0.011	0.086	-0.62	0.138	9	12	14	8	10.75	12	NO
Ricker (Ei)	0.018	0.077	-0.379	0.13	11	5	3	5	6	5	NO
Ricker (Pi)	0.027	0.071	-0.264	0.128	17	3	1	4	6.25	6	NO
Ricker (FrD-peak)	0.013	0.092	-0.537	0.146	10	13	10	12	11.25	13	NO
Ricker (PDO)	0.005	0.104	-0.481	0.216	7	16	5	18	11.5	14	NO
Ricker cyc	0.001	0.073	-0.487	0.112	2	4	6	1	3.25	1	YES
Power	0.024	0.083	-0.519	0.139	15	9	9	9	10.5	10	NO
Larkin	0.024	0.066	-0.28	0.114	15	1	2	2	5	2	NO
KF	0.02	0.081	-0.432	0.135	12	7	4	7	7.5	8	NO

RUN-TIMING: SUMMER

Chilko	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	0.018	0.846	-1.496	1.16	5	26	34	23	22	26	NO
R1C	0.131	0.878	-0.31	1.333	12	29	25	28	23.5	28	NO
R2C	0.116	0.706	-0.336	1.073	11	21	28	20	20	23	NO
RAC	0.004	0.715	-1.036	1.08	3	22	32	21	19.5	21	NO
MRS	0.171	0.824	-0.234	1.233	16	25	12	26	19.75	22	NO
RS1	-0.166	1.103	-0.466	1.967	14	34	31	34	28.25	33	NO
RS2	-0.06	0.906	-0.329	1.469	8	31	27	31	24.25	30	NO
RSC	0.169	0.866	-0.25	1.332	17	28	19	27	22.75	27	NO
RS4yr	-0.103	0.985	-0.378	1.924	10	32	30	33	26.25	32	NO
RS8yr	-0.001	0.847	-0.316	1.362	1	27	26	30	21	24	NO
Ricker	0.301	0.651	-0.245	1.023	27	10	18	10	16.25	16	NO
Ricker (FrD-mean)	0.306	0.646	-0.242	1.014	28	8	15	7	14.5	13	NO
Ricker (Ei)	0.278	0.662	-0.272	1.03	24	15	22	13	18.5	19	NO
Ricker (Pi)	0.292	0.652	-0.269	1.024	26	12	21	11	17.5	18	NO
Ricker (FrD-peak)	0.28	0.662	-0.276	1.029	25	15	23	12	18.75	20	NO
Ricker (PDO)	0.324	0.672	-0.25	1.066	30	18	20	17	21.25	25	NO
Ricker cyc	0.225	0.646	-0.24	1.017	19	8	14	8	12.25	8	NO
Power	0.394	0.74	-0.242	1.13	34	23	16	22	23.75	29	NO
Larkin	0.215	0.593	-0.245	0.976	18	3	17	3	10.25	2	NO
KF	0.244	0.609	-0.285	0.957	20	7	24	2	13.25	9	NO
MRJ	0.169	0.652	-0.188	1.04	15	12	6	15	12	7	YES
RJ1	-0.051	0.893	-0.345	1.52	7	30	29	32	24.5	31	NO
RJ2	0.011	0.756	-0.238	1.184	4	24	13	24	16.25	16	NO
RJC	0.152	0.684	-0.201	1.066	13	19	7	17	14	12	NO
RJ4yr	0.049	0.704	-0.221	1.223	6	20	10	25	15.25	14	NO
RJ8yr	0.082	0.664	-0.217	1.071	9	17	9	19	13.5	10	NO
Power (juv)	0.362	0.594	-0.075	0.978	33	4	1	4	10.5	4	NO
Power (juv) (FrD-mean)	0.264	0.651	-0.205	1.032	23	10	8	14	13.75	11	NO
Power (juv) (Ei)	0.251	0.66	-0.225	1.05	22	14	11	16	15.75	15	NO
Power (juv) (Pi)	0.318	0.579	-0.124	0.996	29	2	4	6	10.25	2	NO
Power (juv) (FrD-peak)	0.336	0.584	-0.122	0.989	31	4	3	5	10.75	5	NO
Power (juv) (PDO)	0.353	0.594	-0.111	1.02	32	4	2	9	11.75	6	NO
KF (juv)	0.249	0.53	-0.161	0.868	21	1	5	1	7	1	NO

Late Stuart	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	0.027	0.652	-19.93	1.041	9	13	20	12	13.5	13	NO
R1C	-0.011	0.365	-0.726	0.676	6	1	1	1	2.25	1	YES
R2C	-0.009	0.407	-0.866	0.815	4	4	2	3	3.25	2	YES
RAC	0.045	0.444	-5.47	0.794	12	5	19	2	9.5	11	NO
MRS	-0.342	0.683	-1.609	1.536	17	14	8	17	14	14	NO
RS1	-0.798	1.036	-4.562	2.651	20	19	18	19	19	19	NO
RS2	-0.627	0.874	-3.743	2.614	18	17	16	18	17.25	17	NO
RSC	-0.251	0.686	-1.751	1.373	16	15	12	15	14.5	15	NO
RS4yr	-0.844	1.157	-2.119	3.865	21	21	14	21	19.25	20	NO
RS8yr	-0.785	1.117	-2.276	3.633	19	20	15	20	18.5	18	NO
Ricker	0.214	0.385	-1.41	0.838	14	2	3	4	5.75	3	YES
Ricker (FrD-mean)	0.004	0.521	-1.741	0.911	2	8	11	7	7	5	NO
Ricker (Ei)	-0.016	0.54	-1.773	0.95	7	10	13	10	10	12	NO
Ricker (Pi)	-0.002	0.557	-1.561	1.046	1	11	6	13	7.75	7	NO
Ricker (FrD-peak)	-0.019	0.537	-1.709	0.949	8	9	10	9	9	10	YES
Ricker (PDO)	-0.01	0.564	-1.593	0.957	5	12	7	11	8.75	9	NO
Ricker cyc	0.039	0.501	-1.503	0.923	11	6	5	8	7.5	6	NO
Power	0.214	0.385	-1.41	0.838	14	2	3	4	5.75	3	NO
Larkin	0.035	0.513	-1.645	0.899	10	7	9	6	8	8	YES
KF	0.078	0.718	-30.82	1.101	13	16	21	14	16	16	NO

Quesnel	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	0.235	1.964	-449.2	2.912	9	20	21	17	16.75	17	NO
R1C	0.076	0.696	-0.175	1.42	3	3	2	2	2.5	1	YES
R2C	0.181	0.837	-0.006	1.742	5	4	1	4	3.5	2	YES
RAC	0.334	1.187	-44.14	2.188	14	13	20	6	13.25	14	NO
MRS	-0.718	1.599	-1.8	3.554	16	18	16	19	17.25	18	NO
RS1	-0.964	1.26	-1.969	2.533	18	15	17	10	15	15	NO
RS2	-1.169	1.433	-1.632	2.974	20	17	15	18	17.5	19	NO
RSC	-1.191	1.938	-2.31	4.567	21	19	18	21	19.75	20	NO
RS4yr	-0.725	1.109	-1.42	2.19	17	7	14	7	11.25	12	NO
RS8yr	-0.99	1.319	-1.345	2.857	19	16	12	16	15.75	16	NO
Ricker	0.208	1.119	-1.262	2.682	6	8	10	13	9.25	7	NO
Ricker (FrD-mean)	0.224	1.125	-1.29	2.633	8	10	11	12	10.25	10	NO
Ricker (Ei)	0.268	1.055	-0.774	2.223	10	6	5	8	7.25	6	YES
Ricker (Pi)	0.322	1.125	-0.989	2.597	13	10	7	11	10.25	10	NO
Ricker (FrD-peak)	0.215	1.166	-1.36	2.797	7	12	13	15	11.75	13	NO
Ricker (PDO)	0.273	1.124	-1.151	2.523	11	9	9	9	9.5	8	NO
Ricker cyc	-0.036	0.841	-0.968	1.877	2	5	6	5	5	4	YES
Power	0.158	1.223	-1.116	2.704	4	14	8	14	10	9	NO
Larkin	0.36	0.633	-0.609	1.612	15	2	4	3	6	5	NO
KF	0.299	0.541	-0.597	1.13	12	1	3	1	4.25	3	NO

Stellako	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	0.001	0.239	-0.548	0.325	1	12	18	7	9.5	8	NO
R1C	-0.012	0.241	-0.276	0.373	4	13	9	14	10	12	NO
R2C	-0.014	0.195	-0.263	0.305	5	1	4	2	3	1	YES
RAC	-0.001	0.233	-0.519	0.322	1	8	16	4	7.25	6	NO
MRS	-0.027	0.316	-0.465	0.435	7	17	14	15	13.25	15	NO
RS1	-0.294	0.471	-0.845	0.941	21	21	21	21	21	20	NO
RS2	-0.23	0.396	-0.708	0.79	20	20	20	20	20	19	NO
RSC	-0.045	0.344	-0.539	0.481	10	19	17	19	16.25	17	NO
RS4yr	-0.09	0.296	-0.439	0.459	18	15	13	16	15.5	16	NO
RS8yr	-0.103	0.302	-0.502	0.459	19	16	15	16	16.5	18	NO
Ricker	0.067	0.23	-0.267	0.335	16	6	6	11	9.75	9	NO
Ricker (FrD-mean)	0.035	0.238	-0.33	0.332	9	11	11	8	9.75	9	NO
Ricker (EI)	0.052	0.225	-0.274	0.313	11	3	8	3	6.25	4	NO
Ricker (PI)	0.059	0.236	-0.264	0.324	13	10	5	6	8.5	7	NO
Ricker (FrD-peak)	0.053	0.234	-0.281	0.334	12	9	10	10	10.25	13	NO
Ricker (PDO)	0.061	0.228	-0.254	0.322	15	4	3	4	6.5	5	NO
Ricker cyc	0.014	0.25	-0.383	0.366	5	14	12	13	11	14	NO
Power	0.067	0.23	-0.267	0.335	16	6	6	11	9.75	9	NO
Larkin	0.059	0.209	-0.198	0.292	13	2	1	1	4.25	2	NO
KF	0.03	0.228	-0.253	0.333	8	4	2	9	5.75	3	YES

RUN-TIMING: LATE

Cultus	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	-0.039	0.039	-39499	0.04	10	10	10	2	8	9	NO
R1C	-0.047	0.047	-46712	0.079	14	14	14	14	14	14	NO
R2C	-0.045	0.045	-45080	0.069	13	13	13	12	12.75	13	NO
RAC	-0.04	0.04	-40362	0.05	11	11	11	8	10.25	11	NO
MRJ	-0.034	0.034	-33651	0.048	2	2	2	3	2.25	2	YES
RJ1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
RJ2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
RJC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
RJ4yr	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
RJ8yr	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Power (juv)	-0.036	0.036	-36459	0.053	9	9	9	11	9.5	10	NO
Power (juv) (FrD-mean)	-0.035	0.035	-34579	0.05	7	7	8	8	7.5	8	NO
Power (juv) (EI)	-0.035	0.035	-34537	0.049	7	7	7	6	6.75	7	YES
Power (juv) (PI)	-0.034	0.034	-34175	0.048	2	2	5	3	3	4	YES
Power (juv) (FrD-peak)	-0.034	0.034	-33999	0.048	2	2	3	3	2.5	3	YES
Power (juv) (PDO)	-0.034	0.034	-34207	0.049	2	2	6	6	4	5	YES
KF (juv)	-0.029	0.029	-28775	0.038	1	1	1	1	1	1	YES
Smolt Jack (Trunc)	-0.044	0.044	-43835	0.073	12	12	12	13	12.25	12	NO
Smolt-Jack (Full)	-0.034	0.034	-34109	0.051	2	2	4	10	4.5	6	NO

Harrison	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	-0.002	0.043	-2.263	0.072	2	6	15	11	8.5	13	NO
R1C	0.012	0.044	-0.77	0.071	11	10	2	9	8	10	NO
R2C	0.014	0.038	-0.653	0.071	12	2	1	9	6	3	NO
RAC	-0.002	0.042	-1.656	0.072	2	5	12	11	7.5	8	NO
MRS	-0.023	0.076	-1.742	0.249	14	14	13	14	13.75	14	NO
RS1	-0.276	0.309	-9.969	1.452	18	18	19	18	18.25	18	NO
RS2	-0.279	0.322	-8.038	1.847	19	19	18	19	18.75	19	NO
RSC	-0.026	0.079	-1.757	0.25	15	15	14	15	14.75	15	NO
RS4yr	-0.082	0.127	-4.167	0.488	17	17	17	17	17	17	NO
RS8yr	-0.048	0.097	-2.291	0.392	16	16	16	16	16	16	NO
Ricker	0.006	0.043	-1.202	0.067	9	6	5	6	6.5	6	YES
Ricker (FrD-mean)	0.006	0.043	-1.319	0.066	6	6	8	5	6.25	5	YES
Ricker (EI)	0.001	0.039	-1.366	0.053	1	3	10	1	3.75	1	NO
Ricker (PI)	0.004	0.045	-1.352	0.065	5	13	9	4	7.75	9	NO
Ricker (FrD-peak)	0.003	0.043	-1.451	0.064	4	6	11	3	6	3	NO
Ricker (PDO)	0.008	0.044	-1.211	0.069	9	10	6	8	8.25	12	NO
Power	0.017	0.037	-0.979	0.072	13	1	3	11	7	7	NO
Larkin	0.007	0.044	-1.288	0.068	8	10	7	7	8	10	NO
KF	0.006	0.04	-1.169	0.06	6	4	4	2	4	2	YES

Late Shuswap	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	-0.183	2.507	-80.58	3.067	5	20	20	18	15.75	16	NO
R1C	0.101	0.762	-0.602	1.453	4	1	1	1	1.75	1	YES
R2C	0.016	1.02	-0.853	1.78	2	9	4	5	5	4	YES
RAC	-0.087	0.823	-0.964	1.524	3	2	7	2	3.5	3	YES
MRS	-0.36	1.069	-1.481	2.274	16	14	14	15	14.75	15	NO
RS1	-1.013	1.842	-2.904	4.173	19	18	19	19	18.75	19	NO
RS2	-0.512	1.297	-2.213	2.546	17	16	17	16	16.5	17	NO
RSC	-0.169	1.086	-1.508	2.229	7	12	15	14	12	14	NO
RS4yr	-1.218	1.906	-2.313	4.813	20	19	18	20	19.25	20	NO
RS8yr	-0.761	1.326	-1.855	2.986	18	17	16	17	17	18	NO
Ricker	0.192	0.97	-1.313	1.826	8	4	13	7	8	7	NO
Ricker (FrD-mean)	0.212	1.006	-1.286	1.921	9	7	12	9	9.25	9	NO
Ricker (EI)	0.286	0.986	-0.878	1.802	14	6	5	6	7.75	6	NO
Ricker (PI)	0.282	1.051	-0.821	2.079	13	11	3	13	10	10	NO
Ricker (FrD-peak)	0.244	1.066	-1.238	1.985	11	12	11	12	11.5	13	NO
Ricker (PDO)	0.248	0.973	-1.198	1.878	12	5	9	8	8.5	8	NO
Ricker cyc	-0.007	0.892	-0.746	1.541	1	3	2	3	2.25	2	YES
Power	0.326	1.024	-1.191	1.927	15	10	8	11	11	12	NO
Larkin	0.228	1.012	-0.907	1.757	10	8	6	4	7	5	YES
KF	0.186	1.086	-1.238	1.924	6	15	10	10	10.25	11	NO

Portage	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	0.008	0.037	-1.222	0.054	13	10	18	12	13.25	17	NO
R1C	-0.001	0.041	-0.685	0.057	2	15	3	15	8.75	10	NO
R2C	0	0.043	-0.909	0.059	1	17	9	16	10.75	12	NO
RAC	0.009	0.034	-0.608	0.05	15	3	2	7	6.75	5	NO
MRS	-0.008	0.037	-1.127	0.051	13	10	16	8	11.75	15	NO
RS1	-0.037	0.064	-2.142	0.095	20	20	20	20	20	20	NO
RS2	-0.017	0.044	-1.22	0.064	18	18	17	18	17.75	18	NO
RSC	-0.003	0.036	-1.113	0.047	5	7	14	2	7	6	NO
RS4yr	-0.021	0.047	-1.484	0.071	19	19	19	19	19	19	NO
RS8yr	-0.015	0.036	-1.12	0.049	17	7	15	5	11	14	NO
Ricker	0.007	0.035	-0.904	0.051	11	6	8	8	8.25	8	NO
Ricker (FrD-mean)	0.002	0.039	-1.001	0.054	3	14	12	12	10.25	11	NO
Ricker (EI)	0.006	0.036	-0.763	0.051	10	7	4	8	7.25	7	YES
Ricker (PI)	0.005	0.038	-0.899	0.055	9	13	7	14	10.75	12	NO
Ricker (FrD-peak)	0.003	0.037	-0.958	0.051	5	10	11	8	8.5	9	NO
Ricker (PDO)	0.002	0.041	-1.015	0.059	3	15	13	16	11.75	15	NO
Ricker cyc	0.004	0.034	-0.91	0.047	7	3	10	2	5.5	2	YES
Power	0.014	0.032	-0.529	0.049	16	1	1	5	5.75	4	NO
Larkin	0.004	0.034	-0.777	0.046	7	3	6	1	4.25	1	YES
KF	0.007	0.033	-0.766	0.048	11	2	5	4	5.5	2	NO

Weaver	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	0.037	0.247	-0.673	0.329	9	19	25	18	17.75	19	NO
R1C	-0.011	0.265	-1.016	0.392	3	28	32	31	23.5	29	NO
R2C	-0.013	0.27	-1.125	0.385	5	31	33	30	24.75	31	NO
RAC	0.036	0.222	-0.659	0.305	8	6	23	10	11.75	9	NO
MRS	0.01	0.212	-0.602	0.277	2	2	19	2	6.25	2	NO
RS1	-0.188	0.389	-0.861	0.622	33	33	30	33	32.25	33	NO
RS2	-0.059	0.258	-0.796	0.335	18	25	29	20	23	27	NO
RSC	-0.014	0.222	-0.744	0.299	6	6	28	4	11	7	NO
RS4yr	0.011	0.212	-0.49	0.299	3	2	14	4	5.75	1	YES
RS8yr	0.003	0.236	-0.546	0.297	1	15	17	3	9	4	NO
Ricker	0.048	0.256	-0.661	0.365	15	23	24	27	22.25	25	NO
Ricker (FrD-mean)	0.034	0.239	-0.63	0.317	7	17	21	12	14.25	12	NO
Ricker (EI)	0.045	0.25	-0.649	0.351	13	21	22	24	20	23	NO
Ricker (PI)	0.062	0.26	-0.588	0.367	19	26	18	28	22.75	26	NO
Ricker (FrD-peak)	0.038	0.245	-0.625	0.331	11	18	20	19	17	17	NO
Ricker (PDO)	0.069	0.194	-0.283	0.252	21	1	8	1	7.75	3	NO
Ricker cyc	0.045	0.248	-0.735	0.339	13	20	27	22	20.5	24	NO
Power	0.083	0.224	-0.411	0.324	26	10	12	14	15.5	15	NO
Larkin	0.038	0.266	-0.717	0.38	11	29	26	29	23.75	30	NO
KF	0.058	0.252	-0.53	0.341	17	22	16	23	19.5	22	NO
MRJ	0.081	0.231	-0.32	0.304	24	12	9	9	13.5	10	NO
RJ1	-0.049	0.362	-0.989	0.517	16	32	31	32	27.75	32	NO
RJ2	0.037	0.264	-0.439	0.361	9	27	13	26	18.75	21	NO
RJC	0.064	0.222	-0.336	0.299	20	6	10	4	10	5	NO
RJ4yr	0.072	0.267	-0.51	0.359	22	30	15	25	23	27	NO
RJ8yr	0.08	0.256	-0.356	0.325	23	23	11	15	18	20	NO
Power (juv)	0.135	0.233	-0.058	0.326	31	14	1	16	15.5	15	NO
Power (juv) (FrD-mean)	0.135	0.238	-0.102	0.336	31	16	2	21	17.5	18	NO
Power (juv) (EI)	0.12	0.226	-0.161	0.314	29	11	3	11	13.5	10	NO
Power (juv) (PI)	0.121	0.231	-0.185	0.32	30	12	5	13	15	14	NO
Power (juv) (FrD-peak)	0.11	0.219	-0.204	0.303	27	5	6	8	11.5	8	NO
Power (juv) (PDO)	0.118	0.223	-0.174	0.327	28	9	4	17	14.5	13	NO
KF (juv)	0.09	0.216	-0.265	0.302	25	4	7	7	10.75	6	NO

Birkenhead	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	0.034	0.244	-0.616	0.359	4	8	12	2	6.5	5	NO
R1C	0.007	0.271	-0.569	0.427	1	13	3	14	7.75	8	NO
R2C	0.008	0.269	-0.843	0.417	2	12	13	13	10	13	NO
RAC	0.039	0.24	-0.736	0.363	5	6	11	3	6.25	3	NO
MRS	-0.041	0.304	-1.134	0.468	7	15	15	15	13	15	NO
RS1	-0.479	0.681	-2.098	1.416	20	20	19	20	19.75	20	NO
RS2	-0.358	0.584	-2.257	1.112	19	19	20	19	19.25	19	NO
RSC	-0.06	0.339	-1.296	0.513	9	16	16	16	14.25	16	NO
RS4yr	-0.207	0.394	-1.377	0.618	17	17	17	17	17	17	NO
RS8yr	-0.214	0.42	-1.642	0.671	18	18	18	18	18	18	NO
Ricker	0.068	0.236	-0.64	0.367	13	1	6	5	6.25	3	NO
Ricker (FrD-mean)	0.065	0.248	-0.687	0.38	12	10	7	9	9.5	10	NO
Ricker (EI)	0.069	0.237	-0.56	0.365	14	2	2	4	5.5	2	NO
Ricker (PI)	0.074	0.238	-0.552	0.375	15	3	1	7	6.5	5	NO
Ricker (FrD-peak)	0.044	0.251	-0.864	0.392	8	11	14	11	11	14	NO
Ricker (PDO)	0.06	0.242	-0.726	0.378	9	7	8	8	8	9	YES
Ricker cyc	0.018	0.277	-0.732	0.402	3	14	10	12	9.75	11	NO
Power	0.083	0.238	-0.598	0.37	16	3	5	6	7.5	7	NO
Larkin	0.062	0.247	-0.729	0.382	11	9	9	10	9.75	11	NO
KF	0.039	0.239	-0.574	0.351	5	5	4	1	3.75	1	YES

Table 6. Top three ranked model forecasts evaluated for each stock for the 2012 forecast, determined by average rank across Performance Measures (MAE, MPE, MRE and RMSE).

RUN TIMING GROUP: EARLY STUART

EARLY STUART	Rank	Return Forecast 10%	25%	50%	75%	90%
Ricker (EI)	1	39,000	61,000	99,000	161,000	270,000
Ricker (PI)	1	37,000	55,000	88,000	142,000	212,000
Ricker	3	36,000	58,000	95,000	156,000	244,000
Ricker (PDO)	3	38,000	58,000	94,000	158,000	245,000

RUN TIMING GROUP: EARLY SUMMER

BOWRON	Rank	Return Forecast 10%	25%	50%	75%	90%
KF	1	1,000	1,000	2,000	4,000	6,000
MRS	2	1,000	2,000	4,000	8,000	14,000
Ricker (PI)	3	2,000	3,000	5,000	8,000	13,000

FENNELL	Rank	Return Forecast 10%	25%	50%	75%	90%
Power	1	6,000	7,000	12,000	20,000	32,000
RAC	2	11,000	19,000	34,000	62,000	105,000
KF	3	2,000	4,000	7,000	13,000	23,000
Ricker	3	4,000	7,000	11,000	19,000	29,000

GATES	Rank	Return Forecast 10%	25%	50%	75%	90%
KF	1	4,000	6,000	12,000	21,000	36,000
RAC	2	46,000	78,000	133,000	228,000	364,000
R2C	3	21,000	36,000	65,000	117,000	199,000

NADINA	Rank	Return Forecast 10%	25%	50%	75%	90%
MRJ	1	17,000	33,000	70,000	147,000	289,000
Ricker (FrD-peak)	2	30,000	47,000	91,000	153,000	274,000
Power (juv) (FrD-peak)	2	27,000	44,000	77,000	133,000	226,000

PITT	Rank	Return Forecast 10%	25%	50%	75%	90%
KF	1	11,000	18,000	35,000	66,000	110,000
Larkin	2	18,000	29,000	45,000	71,000	110,000
TSA	3	22,000	39,000	73,000	136,000	238,000

RAFT	Rank	Return Forecast 10%	25%	50%	75%	90%
Ricker (PDO)	1	22,000	34,000	56,000	88,000	138,000
Ricker-cyc	2	30,000	44,000	67,000	108,000	167,000
Power	2	18,000	27,000	41,000	62,000	91,000

SCOTCH	Rank	Return Forecast 10%	25%	50%	75%	90%
Larkin	1	100	200	300	700	1,400
Ricker	2	300	600	1,000	3,000	8,000
RS1	3	200	500	1,000	4,000	11,000

SEYMOUR	Rank	Return Forecast 10%	25%	50%	75%	90%
Ricker-cyc	1	2,000	4,000	8,000	16,000	29,000
R1C	2	2,000	4,000	8,000	15,000	27,000
Larkin	2	1,000	3,000	5,000	8,000	15,000

RUN TIMING GROUP: SUMMER

CHILKO	Rank	Return Forecast 10%	25%	50%	75%	90%
KF (juv)	1	229,000	342,000	562,000	868,000	1,274,000
Power (juv) (PI)	2	545,000	723,000	1,077,000	1,505,000	2,144,000
Larkin	2	402,000	565,000	871,000	1,268,000	1,853,000

LATE STUART	Rank	Return Forecast 10%	25%	50%	75%	90%
R1C	1	43,000	103,000	269,000	708,000	1,689,000
R2C	2	92,000	220,000	577,000	1,516,000	3,614,000
Power	3	92,000	166,000	338,000	730,000	1,550,000

QUESNEL	Rank	Return Forecast 10%	25%	50%	75%	90%
R1C	1	17,000	33,000	67,000	137,000	261,000
R2C	2	41,000	79,000	167,000	351,000	685,000
KF	3	3,000	5,000	11,000	22,000	47,000

STELLAKO	Rank	Return Forecast 10%	25%	50%	75%	90%
R2C	1	191,000	287,000	453,000	714,000	1,075,000
Larkin	2	189,000	251,000	356,000	519,000	752,000
KF	3	94,000	146,000	223,000	349,000	542,000

RUN TIMING GROUP: LATE

CULTUS	Rank	Return Forecast 10%	25%	50%	75%	90%
KF (juv)	1	1,000	1,000	3,000	7,000	15,000
MRJ	2	2,000	4,000	7,000	15,000	29,000
Power (juv) (FrD-peak)	3	1,000	3,000	6,000	12,000	22,000

HARRISON	Rank	Return Forecast 10%	25%	50%	75%	90%
Ricker (Ei)	1	12,000	26,000	54,000	114,000	235,000
KF	2	20,000	39,000	83,000	184,000	401,000
Ricker (FrD-peak)	3	12,000	25,000	56,000	161,000	357,000
R2C	3	11,000	22,000	49,000	108,000	218,000

LATE SHUSWAP	Rank	Return Forecast 10%	25%	50%	75%	90%
R1C	1	2,000	5,000	12,000	29,000	64,000
Ricker-cyc	2	1,000	3,000	8,000	19,000	46,000
RAC	3	6,000	13,000	28,000	63,000	132,000

PORTAGE	Rank	Return Forecast 10%	25%	50%	75%	90%
Larkin	1	500	1,000	2,000	4,000	9,000
KF	2	200	500	1,000	3,000	5,000
Ricker-cyc	2	400	900	2,000	4,000	7,000

WEAVER	Rank	Return Forecast 10%	25%	50%	75%	90%
RS4yr	1	12,000	23,000	47,000	96,000	181,000
MRS	2	16,000	27,000	48,000	85,000	141,000
Ricker (PDO)	3	28,000	47,000	84,000	149,000	254,000

BIRKENHEAD	Rank	Return Forecast 10%	25%	50%	75%	90%
KF	1	27,000	45,000	85,000	155,000	298,000
Ricker (Ei)	2	71,000	123,000	209,000	363,000	611,000
RAC	3	50,000	110,000	262,000	626,000	1,373,000
Ricker	3	101,000	153,000	263,000	427,000	714,000

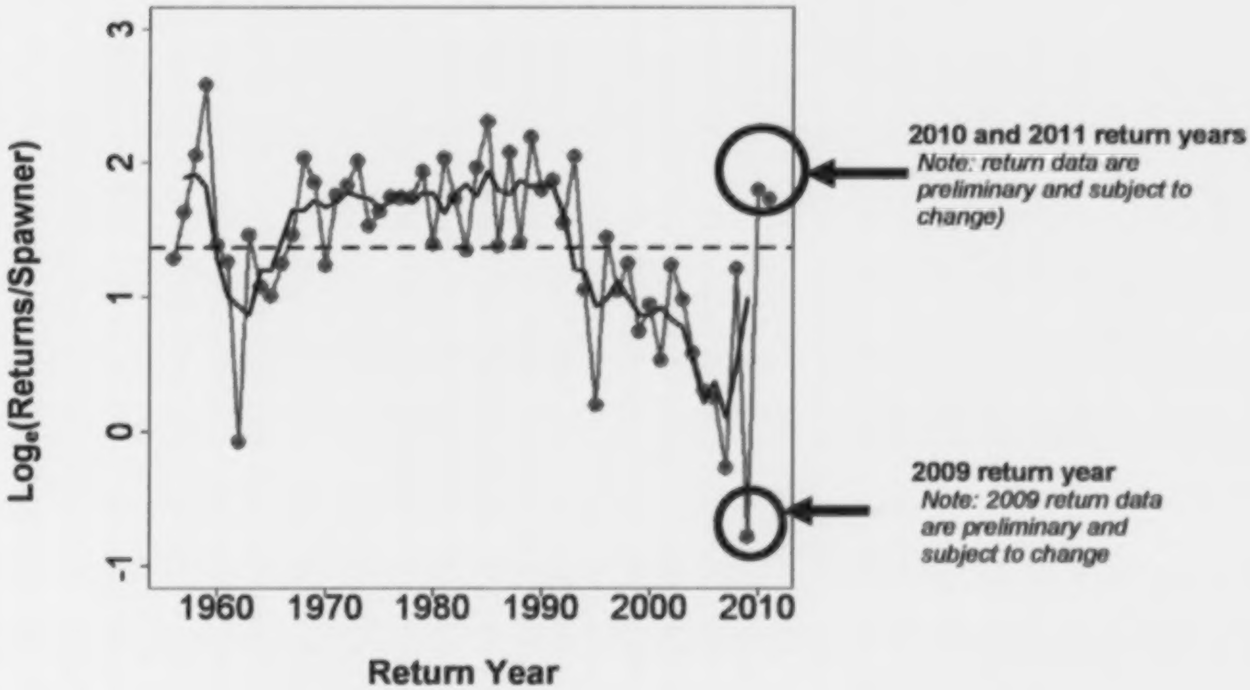


Figure 1. Total Fraser Sockeye productivity (log_e(returns/spawner)) up to the 2011 return year. The light blue line represents annual productivity and the dark blue line is the associated smoothed four year running average. The red dashed line represents the long-term average productivity. Return data for 2009 and 2010 are preliminary, and for 2011 data are in-season estimates only. This productivity time series does not consider stock age structure, which is required for a more thorough analysis of productivity. Trends are driven by the most abundant Summer Run stocks. Return data are provided by the Pacific Salmon Commission.

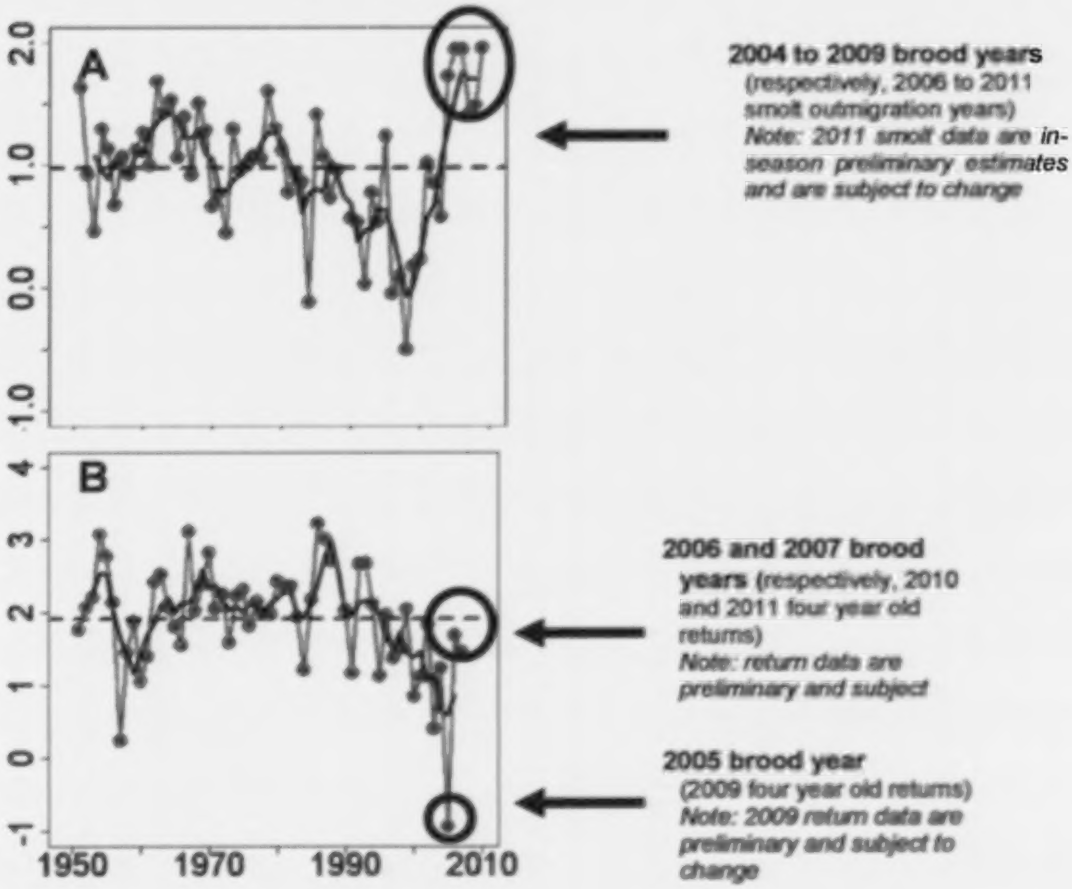
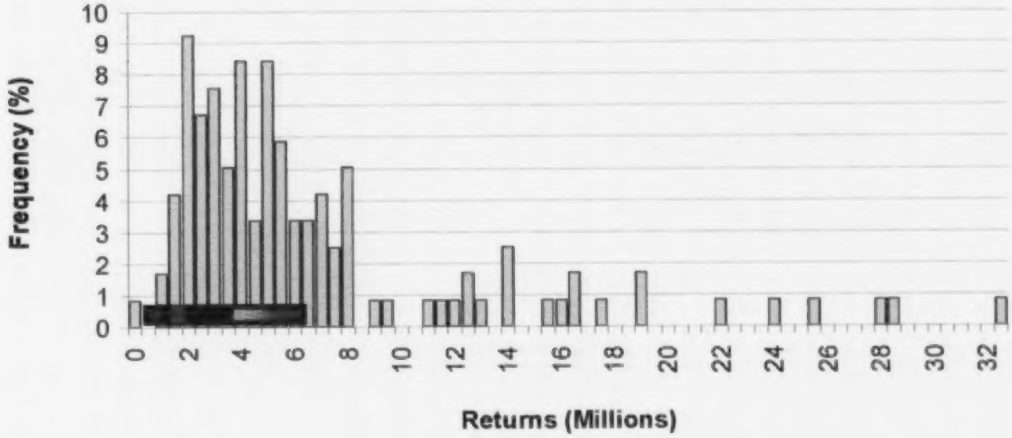


Figure 2. Chilko River Sockeye A. freshwater ($\log_e$ smolts per egg) and B. marine ($\log_e$ recruits per smolt) annual survival (light blue lines) and smoothed four-year running average survival (dark blue lines). Red dashed lines in both plots indicate long-term average survival.

A.



B.

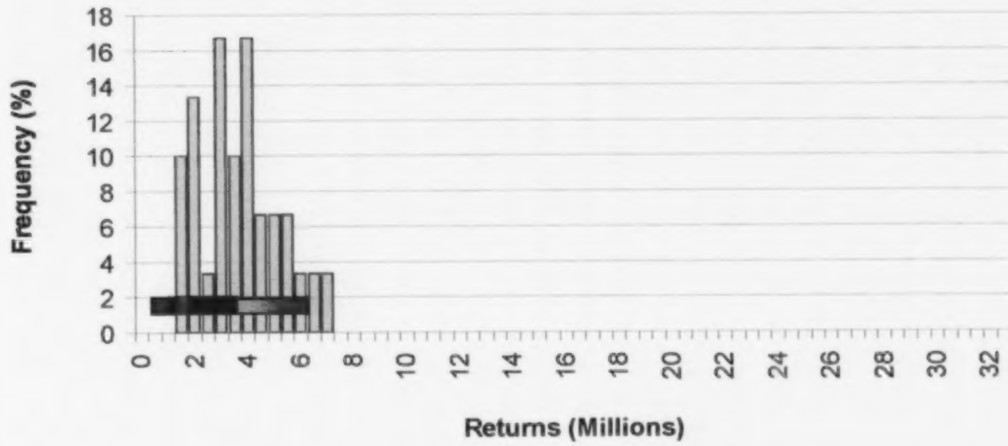


*Figure 3. Frequency plots of historical Fraser Sockeye returns on **A.** all cycles, and **B.** the 2012 cycle line. X-axes indicate return abundances in millions and y-axes indicate the frequency (%) of abundances in each interval. Plots are overlain with the total 2012 forecast cumulative probability distribution, from the 10% to the 90% probability levels. Colour-coding differentiates the probability levels (10%, 25%, 50%, 75, 90%), red colouring indicates the 50% probability level.*

APPENDIX 1: 'RECENT MODEL PERFORMANCE' SENSITIVITY ANALYSIS

An additional sensitivity analysis was performed to determine 'Recent Model Performance', using the jack-knife performance time-series from only the more recent, lower productivity period (two most recent cycles of available stock-recruitment data: 1997-2004) to calculate performance measures and evaluate models. This analysis is not presented as an alternative 2012 forecast. The evaluation identified models that specifically performed well over the range of lower productivity seen in the last eight brood years, as an investigation into the sensitivity of the jack-knife approach. Forecast models were chosen using the same ranking procedure as in the 2012 forecast.

Miscellaneous stocks, for which recruitment data is unavailable, were forecast using the product of their brood year escapements and the average recent (brood years 1997-2004) productivity for spatially and temporally similar stocks that have stock recruitment data, as identified in Table 1 (footnotes e, f, g, h, i, l).

According to this analysis there is a one in ten chance (10% probability) the Sockeye return will be at or below 600,000, and a nine in ten chance (90% probability) it will be at or below 5.9 million. The mid-point of this distribution (50% probability) is 1.7 million (there exists a one in two chance the return will be above or below this value assuming the productivities implied by the best models evaluated over the recent data set). The total forecast for this sensitivity analysis across all stocks is quite similar to that presented as the 2012 forecast (21% difference between the 2012 forecast and 'Recent Model Performance' scenario at the 50% probability level), with almost half of the stocks using identical models. In cases where the performance of a single model was similar or identical to the 2012 forecast for a given stock, the same model was used to forecast the return (this occurred in 7 of the 19 stocks).

Despite the below average (or above for Harrison) stock productivity observed in recent years for most Fraser Sockeye stocks, the model composition of the 'Recent Model Performance' analysis includes a mixture of models that consider both recent (RS4yr, KF and Smolt-Jack (trunc)) and long-term productivity periods (RAC, MRS, power, Ricker-environmental covariate and Larkin). Recent productivity models did not necessarily perform better in the more recent period than long-term average productivity models. Much of the deviation from the 2012 forecast (14% out of the total 21%) is attributed to Summer Run stocks (Late Stuart: 8%; Stellako: 5%; and Quesnel: 1%). Harrison contributes 6% and Early Stuart also contributes 3% to the total difference. 'Recent Model Performance' forecasts were generally smaller than those in the 2012 forecast, given the productivity changes that occurred in the recent time series. 'Recent Model Performance' forecasts for Early Stuart (KF model) and Late Stuart (RS4yr model) are lower than corresponding 2012 forecasts (Ricker (Ei) and power models, respectively), due to their use of recent productivity models. For Harrison, the recent productivity model produced a higher forecast, as this stock has experienced an increase in productivity. For Stellako and Quesnel, differences for this analysis are not specific to the use of recent productivity models. Miscellaneous stock forecasts account for an additional 3% of the total 21% difference.

Early Stuart Run

In the 'Recent Model Performance' analysis for Early Stuart, the top ranked models (based on the average rank across all four performance measures: MRE, MAE, MPE, RMSE) are KF, RS4yr (tied second) and RS8yr (tied second) (Table A4). For each individual performance measure, these models each ranked within the top 50% (10 out of 20) of all models compared for this stock (Table A4). Forecasts produced by the top ranked models were similar, with the smallest forecast (RS4yr) varying by 18% from the largest forecast (KF) (percent difference between smallest and largest forecasts at the 50%-median probability level, calculated as a

percentage of the largest forecast) (Table A5). The KF model was used for the 'Recent Model Performance' forecast, as it ranked first on average across performance measures, and it ranked first on each individual performance measure except MPE (ranked third) (Table A4). Given the assumptions underlying the KF model, there is a one in four chance (25% probability) the Early Stuart Sockeye return will be below 27,000 (1.8 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 73,000 (5.0 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 44,000 (2.9 age-4 R/EFS) is well below the average return on this cycle (120,000) (Tables A1 and A2). The age-5 component of the 'Recent Model Performance' forecast is expected to contribute 5% of the total return (at the 50% probability level) (Table A3).

**Note: For the remaining stock sections the following were consistently applied: top ranked models were identified based on the average rank across all four performance measures: MRE, MAE, MPE, RMSE; and top model forecasts were compared according to the percent difference between smallest and largest forecasts at the 50%-median probability level, calculated as a percentage of the largest forecast. Unless otherwise noted, in all subsequent sections the top three models each ranked within the top half of all models compared for the stock. Also, comparisons of ranks on individual performance measures refer only to the top three models.*

Early Summer Run

Bowron

In the 'Recent Model Performance' analysis for Bowron, the top ranked models are KF, RS4yr and R1C (Table A4). Forecasts produced by the top ranked models were not similar, diverging by as much as 65% (largest percent difference between these forecasts at the 50%-median probability level) (Table A5). The RS4yr model produced the lowest forecast, reflecting this stock's low productivity in the last four brood years. The R1C model, which does not use the extremely low 2008 brood year EFS for Bowron as a predictor variable, produced the highest forecast. The KF model was used for the 'Recent Model Performance' forecast, as it ranked first on average across performance measures, and it ranked first on each individual performance measure (Table A4). This forecast is identical to the 2012 forecast (Tables A1 and A2).

Fennell

In the 'Recent Model Performance' analysis for Fennell, the top ranked models are RAC, TSA and power (Table A4). Forecasts produced by the top ranked models were not similar, varying by as much as 65% (Table A5). This difference in forecasts is attributed to the relatively large forecasts generated by the non-parametric models (RAC and TSA), which do not use the extremely low 2008 brood year EFS for this stock as a predictor variable. Although the power model did not rank first across all performance measures, the power model was used for the 'Recent Model Performance', since, unlike the first and second ranked non-parametric models, it takes into consideration the recent very low brood year escapements for Fennell (Table A4). This forecast is identical to the 2012 forecast (Tables A1 and A2).

Gates

In the 'Recent Model Performance' analysis for Gates, the top ranked models are KF, RS8yr and RS4yr (Table A4). Forecasts produced by the top ranked models were similar, varying at most by 18% (Table A5). The KF model was chosen for the 'Recent Model Performance' forecast, as it ranked first on average across performance measures, and it ranked first on each individual performance measure except MPE (ranked fourth). This forecast is identical to the 2012 forecast (Tables A1 and A2).

Nadina

In the 'Recent Model Performance' analysis for Nadina, the top ranked models are MRJ, KF and Ricker (FrD-peak) (Table A4). Forecasts produced by the top ranked models varied at most by 39% (Table A5). The MRJ model was used for the 'Recent Model Performance' forecast, as it ranked first on average across performance measures, and it ranked highest on each individual performance measure except MPE (ranked third) (Table A4). This forecast is identical to the 2012 forecast (Tables A1 and A2).

Pitt

In the 'Recent Model Performance' analysis for Pitt, the top ranked models are KF, Larkin (tied second) and Ricker (Ei) (tied second) (Table A4). For each individual performance measure, the KF and Ricker (Ei) models each ranked within the top 50% (10 out of 20) of all models compared for this stock (Table A4). Forecasts produced by these two models varied by as much as 53% (Table A5). The KF model produced a lower forecast, reflecting this stocks recent lower productivity. The KF model was used for the 'Recent Model Performance' forecast, as it ranked first on average across performance measures, though on an individual basis, the Ricker (Ei) model ranked slightly higher than the KF model on the MPE and RMSE performance measures. The KF forecast is identical to the 2012 forecast (Tables A1 and A2).

Raft

In the 'Recent Model Performance' analysis for Raft, the top ranked models are power, Ricker-cyc and Larkin (Table A4). Forecasts produced by the top ranked models varied by as much as 44% (Table A5). The power model was used for the 'Recent Model Performance' forecast, as it ranked first on average across performance measures, and it ranked first on each individual performance measure except MPE (ranked third) (Table A4). Given the assumptions underlying the power model, there is a one in four chance (25% probability) the Raft Sockeye return will be below 27,000 (2.9 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 62,000 (9.6 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 41,000 (5.4 age-4 R/EFS) is close to the average return on this cycle (57,000) (Tables A1 and A2). The age-5 component of the 'Recent Model Performance' forecast is expected to contribute 54% of the total return (at the 50% probability level) (Table A3).

Scotch

In the 'Recent Model Performance' analysis for Scotch, the top ranked models are Larkin, RSC and RS2 (Table A4). For each individual performance measure, the Larkin and RS2 models each ranked within the top 50% (10 out of 20) of all models compared for this stock (Table A4). These two models produced widely different forecasts, varying by 91% (Table A5). The Larkin model forecast is smaller than the Ricker model, which can be attributed to the Larkin model's consideration of delayed density-dependent interactions between the 2008 brood year escapement and the relatively high escapements of previous years for Scotch. In particular, the escapement in 2006 (73,000 EFS) was the highest escapement on record for this stock. The Larkin model was used for the 'Recent Model Performance' forecast, as it ranked first on average across performance measures, though across individual performance measures other top models outperformed the Larkin (Table A4). This forecast is identical to the 2012 forecast (Tables A1 and A2).

Seymour

In the 'Recent Model Performance' analysis for Seymour, the top ranked models are Larkin, MRS and RS2 (Table A4). For each individual performance measure, the Larkin and RS2 models rank within the top 50% (10 out of 20) of all models compared for this stock (Table A4). Forecasts produced by these two models varied at most by 26% (Table A5). The Larkin model was used for the 'Recent Model Performance' forecast, as it ranked first on average across performance measures, though on an individual basis, other top models outperformed the Larkin model on three of four performance measures (Table A4). Given the assumptions underlying the Larkin model, there is a one in four chance (25% probability) the Seymour Sockeye return will be below 3,000 (4.2 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 8,000 (13.3 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 5,000 (7.4 age-4 R/EFS) is well below the average return on this cycle (34,000) (Tables A1 and A2). The age-5 component of the 'Recent Model Performance' forecast is expected to contribute 56% of the total return (at the 50% probability level) (Table A3).

Summer Run

Chilko

In the 'Recent Model Performance' analysis for Chilko, the top ranked models are KF (juv), RS8yr and RS4yr (Table A4). Forecasts produced by the top ranked models were not similar, varying by as much as 67% (Table A5). The KF (juv) model was used for the 'Recent Model Performance' forecast, as it ranked first on average across performance measures, and it ranked first on each individual performance measure. This forecast is identical to the 2012 forecast (Tables A1 and A2).

Late Stuart

In the 'Recent Model Performance' analysis for Late Stuart, the top ranked models are RS4yr, KF and RAC (Table A4). Forecasts produced by the top ranked models varied at most by 30% (Table A5). The RS4yr and RAC models produced very similar forecasts, while the KF forecast was the largest. The RS4yr model was used for the 'Recent Model Performance' forecast, as it ranked first on average across performance measures, and it ranked high on each individual performance measure. Given the assumptions underlying the RS4yr model, there is a one in four chance (25% probability) the Late Stuart Sockeye return will be below 59,000 (1.0 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 500,000 (8.6 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 171,000 (2.9 age-4 R/EFS) is very similar to the average return on this cycle (187,000) (Tables A1 and A2). The age-5 component of the 'Recent Model Performance' forecast is expected to contribute 1% of the total return (at the 50% probability level) (Table A3).

Quesnel

In the 'Recent Model Performance' analysis for Quesnel, the top ranked models are RAC, KF and Larkin (Table A4). Forecasts produced by the top ranked models were not similar, varying by 78% (Table A5). The KF model, in particular, produced a low forecast, reflecting this stocks recent lower productivity. The RAC model was used for the 'Recent Model Performance' forecast, as it ranked first on average across performance measures, and it ranked first on each individual performance measure except MRE (ranked fourth) (Table A4). Given the assumptions underlying the RAC model, there is a one in four chance (25% probability) the Quesnel Sockeye return will be below 15,000 (1.4 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 144,000 (13.5 age-4 R/EFS) in 2012. The median (one in two chance: 50%

probability) forecast of 46,000 (4.3 age-4 R/EFS) is similar to the average return on this cycle (57,000) (Tables A1 and A2). The age-5 component of the 'Recent Model Performance' forecast is expected to contribute 76% of the total return (at the 50% probability level) (Table A3).

Stellako

In the 'Recent Model Performance' analysis for Stellako, the top ranked models are Larkin, KF and R1C (Table A4). Forecasts produced by the top ranked models varied at most by 37% (Table A5). The KF model, in particular, produced a lower forecast, reflecting this stocks recent lower productivity. The Larkin model was used for the 'Recent Model Performance' forecast, as it ranked first on average across performance measures, and it ranked high on each individual performance measure (Table A4). Given the assumptions underlying the Larkin model, there is a one in four chance (25% probability) the Stellako Sockeye return will be below 251,000 (2.6 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 519,000 (6.2 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 356,000 (3.9 age-4 R/EFS) is close to the average return on this cycle (467,000) (Tables A1 and A2). The age-5 component of the 'Recent Model Performance' forecast is expected to contribute 19% of the total return (at the 50% probability level) (Table A3).

Late Run

Cultus

In the 'Recent Model Performance' analysis for Cultus, the top ranked models are Smolt-Jack (truncated), KF (juv) and R1C (Table A4). Forecasts produced by the top ranked models were not similar, varying by up to 68% (Table A5). The R1C model produced the smallest forecast, since it uses the very low returns from 2008 as the forecast. The Smolt-Jack (truncated) model was used for the 'Recent Model Performance' forecast, as it ranked first on average across performance measures, and it ranked first on each individual performance measure (Table A4). Given the assumptions underlying the Smolt-Jack (truncated) model, there is a one in four chance (25% probability) the Cultus Sockeye return will be below 2,000 (2% age-4 marine survival) and a three in four chance (75% probability) the return will be below 5,000 (4% age-4 marine survival) in 2012. The median (one in two chance: 50% probability) forecast of 4,000 (2% age-4 marine survival) is well below the average return on this cycle (21,000) (Tables A1 and A2). The age-5 component of the 'Recent Model Performance' forecast is expected to contribute 3% of the total return (at the 50% probability level) (Table A3).

Harrison

In the 'Recent Model Performance' analysis for Harrison, the top ranked models are Ricker (Ei), KF and Ricker (FrD-peak) (Table A4). Forecasts produced by the top ranked models varied at most by 35% (Table A5). The KF model produced the largest forecast, reflecting recent increases in productivity for this stock. The Ricker (Ei) model was used for the 'Recent Model Performance' forecast, as it ranked first on average across performance measures, and it ranked first on each individual performance measure except MPE (ranked second) (Table A4). Given the assumptions underlying the Ricker (Ei) model, there is a one in four chance (25% probability) the Harrison Sockeye return will be below 26,000 (2.3 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 114,000 (14.1 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 54,000 (5.9 age-4 R/EFS) is above the average return on this cycle (19,000) (Tables A1 and A2). The age-5 component of the 'Recent Model Performance' forecast is expected to contribute 52% of the total return (at the 50% probability level) (Table A3).

Late Shuswap

In the 'Recent Model Performance' analysis for Late Shuswap, the top ranked models are RAC, R2C and Ricker (Pi) (Table A4). Forecasts produced by the top ranked models varied at most by 38% (Table A5). Given the extremely low 2008 brood year escapement for Late Shuswap, the top ranked biological model (Ricker (Pi)) was used to generate this 'Recent Model Performance' forecast, as this model, unlike the first and second ranked non-parametric models, uses brood year escapement as a predictor variable. The Ricker (Pi) model also ranked high on average across performance measures, and it ranked high on each individual performance measure (Table A4). Given the assumptions underlying the Ricker (Pi) model, there is a one in four chance (25% probability) the Late Shuswap Sockeye return will be below 2,000 (2.4 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 134,000 (9.6 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 18,000 (4.8 age-4 R/EFS) is below the average return on this cycle (29,000) (Tables A1 and A2). The age-5 component of the 'Recent Model Performance' forecast is expected to contribute 98% of the total return (at the 50% probability level) (Table A3).

Portage

In the 'Recent Model Performance' analysis for Portage, the top ranked models are KF, power and RAC (Table A4). Forecasts produced by the top ranked models were widely different, varying by 93% (Table A5). The KF model, in particular, generated a low forecast, reflecting the recent decline in productivity for this stock. In contrast, the non-parametric (RAC) model produced a high forecast, since it does not use the extremely low 2008 brood year escapement as a predictor variable in its forecast. The KF model was used for the 'Recent Model Performance' forecast, as it ranked first on average across performance measures, and it ranked first on each individual performance measure except MPE (ranked second) (Table A4). Given the assumptions underlying the KF model, there is a one in four chance (25% probability) the Portage Sockeye return will be below 500 (3.2 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 3,000 (22.2 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 1,000 (9.5 age-4 R/EFS) is well below the average return on this cycle (16,000) (Tables A1 and A2). The age-5 component of the 'Recent Model Performance' forecast is expected to contribute 45% of the total return (at the 50% probability level) (Table A3).

Weaver

In the 'Recent Model Performance' analysis for Weaver, the top ranked models are Ricker (PDO), MRS, Ricker (FrD-peak) (tied third) and power (juv) (FrD-peak) (tied third) (Table A4). Forecasts produced by the top ranked models were not similar, varying by up to 60% (Table A5). The top ranked Ricker (PDO) model, which uses the PDO environmental variable as a covariate, produced a forecast that was approximately double those of other top ranked models. Given that the PDO value for the 2008 brood year was overall positive (anomalously warm), models that include this covariate are expected to generate a lower, not higher forecast. Therefore, the correlation between PDO and Weaver survival was considered to be spurious and this first ranked model was not considered. The power model that uses Fraser peak discharge as an environmental covariate, and the 2008 brood year juvenile data as a predictor variable produced a much higher forecast than the Ricker (FrD-peak) model, which uses EFS as its predictor variable. This is, in part, attributed to the higher than average juvenile survival in the 2008 brood year for Weaver, but it is also the result of the environmental covariate influencing each of these models differently (juvenile versus EFS). Given that the age-4 productivities produced by the power (juv) (FrD-peak) model are well outside the range observed for Weaver, the second ranked MRS model was selected for the 'Recent Model Performance' forecast (Table A4). The MRS model ranked second across all performance

measures and it ranked relatively high across the four performance measures individually (Table A4). Given the assumptions underlying the MRS model, there is a one in four chance (25% probability) the Weaver Sockeye return will be below 27,000 (6.8 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 85,000 (21.1 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 48,000 (12.0 age-4 R/EFS) is well below the average return on this cycle (345,000) (Tables A1 and A2). The age-5 component of the 'Recent Model Performance' forecast is expected to contribute 85% of the total return (at the 50% probability level) (Table A3).

Birkenhead

In the 'Recent Model Performance' analysis for Birkenhead, the top ranked models are RS4yr, RS1 and R1C (Table A4). Forecasts produced by the top ranked models were not similar, varying by up to 68% (Table A5). The RS1 model produced the lowest forecast, given the extremely low productivity for this stock in the recent brood year. The RS4yr and R1C forecasts were similar, varying by 15%. The RS4yr model was used for the 'Recent Model Performance' forecast, as it ranked first on average across performance measures, and it ranked high on each individual performance measure (Table A4). Given the assumptions underlying the RS4yr model, there is a one in four chance (25% probability) the Birkenhead Sockeye return will be below 27,000 (0.5 age-4 R/EFS) and a three in four chance (75% probability) the return will be below 148,000 (2.8 age-4 R/EFS) in 2012. The median (one in two chance: 50% probability) forecast of 63,000 (1.2 age-4 R/EFS) is well below the average return on this cycle (281,000) (Tables A1 and A2). The age-5 component of the 'Recent Model Performance' forecast is expected to contribute 87% of the total return (at the 50% probability level) (Table A3).

*Table A1. '**Recent Model Performance**' Fraser Sockeye forecasts for 2012 are presented by stock and timing group from the 10% to 90% probability levels (columns A and J to N). The selected models for each stock are presented in column B. Average run sizes are presented across all cycles (H) and for the 2012 cycle (I). Brood year escapements (smolts for Chilko and Cultus) for age-4 (2008) and age-5 (2007) recruits returning in 2012 (columns C and D) are presented and colour coded relative to their cycle average from 1948-2004 (brood year). Forecasted returns (column G), that correspond to the 50% probability level (column L), and geometric average age-4 productivities $\log_e$(R/EFS) associated with returns from the last eight (1998-2005) (column E) and last four brood years (2002-2005) (column F) are also colour coded relative to their cycle average. Color codes represent the following: Red (< average), yellow (average) and green (> average).*

Run timing group / Stocks	Forecast Model[b]	BY (08) (EFS)	BY (07) (EFS)	Prod. (8yr)	Prod. (4yr)	Rel 2012	Mean Run Size: all cycles[c]	Mean Run Size: 2012 cycle[d]	Probability that Return will be at/or Below Specified Run Size[a]: 10%	25%	50%	75%	90%
Early Stuart	KF	14,400	2,400	2.5	2.1		311,000	128,000	17,000	27,000	44,000	73,000	123,000
Early Summer							518,000	517,000	88,000	150,000	288,000	580,000	913,000
(total excluding miscellaneous)							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Bowron	KF	300	1,100	2.8	2.3		38,000	27,000	1,000	1,000	2,000	4,000	6,000
Fennell	Power	200	6,800	4.0	3.2		25,000	34,000	5,000	7,000	12,000	20,000	32,000
Gates	KF	1,800	1,100	4.5	3.1		53,000	135,000	4,000	8,000	12,000	21,000	36,000
Nadina	MRJ	10,200	1,000	3.0	3.5		80,000	137,000	17,000	33,000	70,000	147,000	286,000
Pitt	KF	5,400	16,900	0.3	0.1		72,000	81,000	11,000	18,000	38,000	66,000	110,000
Raft	Power	3,600	8,100	2.7	2.0		32,000	57,000	19,000	27,000	41,000	62,000	91,000
Scotch	Larkin	100	4,800	6.7	3.5		78,000	12,000	100	200	300	700	1,000
Seymour	Larkin	300	5,800	5.4	3.0		131,000	34,000	1,000	3,000	5,000	8,000	15,000
Misc[e]	RS (So/Se)	500	3,800			–	NA	NA	1,000	6,000	9,000	11,000	14,000
Misc[f]	RS (Ra/Fe)	200	1,000			–	NA	NA	1,000	2,000	2,000	6,000	8,000
Misc[g]	RS (Ra/Fe)	1,000	8,000			–	NA	NA	10,000	14,000	21,000	56,000	60,000
Misc[h]	RS (Esum)	10,700	1,100			–	NA	NA	18,000	37,000	84,000	187,000	336,000
Misc[i]	RS (Esum)	100	2,000			–	NA	NA	1,000	2,000	4,000	6,000	10,000
Summer							3,730,000	2,591,000	440,000	697,000	1,130,000	2,001,000	3,749,000
Chilko[j]	KF (jw)	11.8 M	25.2 M	0.02	0.02		1,350,000	1,790,000	229,000	342,000	580,000	880,000	1,274,000
Late Stuart	RS4yr	57,000	4,100	2.8	2.1		560,000	107,000	22,000	58,000	171,000	580,000	1,311,000
Quesnel	RAC	2,500	33,800	1.0	1.0		1,358,000	57,000	5,000	10,000	48,000	144,000	455,000
Stellako	Larkin	75,600	19,500	1.5	0.7		462,000	407,000	189,000	251,000	308,000	519,000	702,000
Late							3,059,000	711,000	44,000	86,000	193,000	486,000	1,062,000
(total excluding miscellaneous)							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cultus[j,k]	Smolt-Jack (trunc.)	145,300	341,000	0.02	0.02		38,000	21,000	2,000	2,000	4,000	5,000	7,000
Harrison[l]	Ricker (Ei)	4,400	100,500	6.3	3.4		60,000	10,000	12,000	36,000	94,000	114,000	230,000
Late Shuswap	Ricker (Pi)	50	51,300	2.4	0.7		2,152,000	20,000	1,000	2,000	19,000	134,000	271,000
Portage	KF	50	400	3.5	2.2		40,000	10,000	200	500	1,000	3,000	5,000
Weaver	MRS	500	11,800	8.8	3.9		383,000	345,000	10,000	27,000	48,000	85,000	141,000
Birkenhead	RS4yr	6,600	54,500	1.8	0.8		386,000	391,000	12,000	27,000	63,000	148,000	319,000
Misc. non-Shuswap		500	2,500			–	NA	NA	1,000	5,000	7,000	10,000	14,000
TOTAL							-	-	[illegible]	646,000	1,670,000	3,183,000	5,867,000
(TOTAL excluding miscellaneous)							[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

a. Probability that return will be at, or below, specified projection.
b. See Table 5 for model descriptions
c. Sockeye: 1953-2009 (depending on start of time series)
d. Sockeye: 1956-2008 (depending on start of time series)
e. Unforecasted miscellaneous Early Summer Stocks (Early Shuswap stocks: S.Thompson; used Scotch/Seymour R/EFS (1997-2004))
f. Unforecasted miscellaneous Early Summer stocks (N. Thomson tributaries; used Raft/Fennell R/EFS (1997-2004)).
g. North Thompson River (used Raft/Fennell R/EFS (1997-2004))
h. Chilliwack Lake and Dolly Varden Creek (used Early Summer R/EFS (1997-2004))
i. Nahatlach River & Lake (used Early Summer R/EFS(1997-2004))
j. Brood year smolts in columns C & D (not effective females)
k. For Cultus, this smolt-jack forecast used a truncated (brood years 1997-2004) marine survival time series.
l. Harrison are age-4 (column C) and age-3 (column D).
m. Unforecasted miscellaneous Late Run stocks (Harrison Lake down stream migrants including Big Silver, Cogburn, etc.; used Birkenhead R/EFS)

Definitions: BY: Brood year; BY08: brood year 2008; BY07: brood year 2007; EFS: effective female spawners; Prod. (8yr), Prod. (4yr): Productivity in age-4 recruits-per-effective female spawners in the last 8 yrs (1998-2005) or last 4 yrs (2001-2005).

Table A2. For each of the 19 forecasted stocks (column A), geometric average age-4 productivities log_e(R/EFS) are presented for the first part of the time series (up to and including 1979) (column B), the latter part of the time-series, which is used as a reference period (1980-2005) (column C), and the most recent eight (1998-2005) (column D), and four brood years (2002-2005) (column E), for comparison. Age-4 productivities associated with the various probability levels of the 'Recent Model Performance' 2012 forecast (based on Table A1 forecasts and escapements) are presented in columns (F) to (J). Forecast productivities are presented as R/EFS, but the log_e (R/EFS) was used to determine colour codes for columns (B) to (E) (see methods in Grant et al. 2010). Colour codes represent the following: Red (< average), yellow (average) and green (>average).

A	B	C	D	E	F	G	H	I	J
Run timing group / Stocks	Early Time Series Avg R/EFS (up to 1979)	Ref. Period Avg R/EFS (1980-2005)	Last 8 yrs Avg R/EFS (1998-2005)	Last 4 yrs Avg R/EFS (2002-2005)	"Recent Productivity" 2012 forecast productivities (R/EFS) for each probability level in Table 3 by stock				
					10%	25%	50%	75%	90%
Early Stuart	9.5	3.9	2.5	2.1	1.1	1.8	2.9	5.0	8.4
Early Summer									
Bowron	9.0	4.8	2.8	2.3	1.5	2.2	4.4	7.3	12.7
Fennell	20.0	4.1	4.0	3.2	6.2	10.5	19.0	34.8	57.1
Gates	17.0	7.3	4.5	3.1	1.7	3.1	6.0	11.0	19.3
Nadina	10.1	5.3	3.0	3.5	1.6	3.2	6.7	14.2	27.7
Pitt	2.6	0.6	0.3	0.1	0.1	0.2	0.8	1.4	2.5
Raft	7.9	4.5	2.7	2.0	1.7	2.9	5.4	9.6	15.6
Scotch		6.7	6.7	3.5	0.5	0.9	1.9	4.0	8.8
Seymour	10.9	5.1	5.4	3.6	2.1	4.2	7.4	13.3	22.1
Summer									
Chilko[a]	0.08	0.06	0.02	0.02	0.01	0.02	0.04	0.06	0.10
Late Stuart	11.3	7.3	2.6	2.1	0.4	1.0	2.9	8.6	22.4
Quesnel[b]	10.2	4.8	1.0	1.0	0.5	1.4	4.3	13.5	37.9
Stellako	10.1	4.5	1.5	0.7	1.8	2.6	3.9	6.2	9.5
Late									
Cultus[a]	0.05	0.04	0.02	0.02	0.01	0.02	0.02	0.04	0.05
Harrison	2.3	4.9	6.3	3.4	1.1	2.3	5.9	14.1	33.4
Late Shuswap[b]	5.9	4.0	2.4	0.7	1.2	2.4	4.8	9.6	16.9
Portage	20.9	8.8	3.5	2.2	1.6	3.2	9.5	22.2	52.4
Weaver	15.2	10.2	8.8	3.9	4.1	6.8	12.0	21.1	35.3
Birkenhead	9.4	3.0	1.6	0.9	0.2	0.5	1.2	2.8	6.1

a. Chilko and Cultus are marine survival (recruits per smolt).
b. Quesnel and Late Shuswap are cycle averages.

Table A3. Age composition of forecasted 'Recent Model Performance' returns for each stock at the 50% probability level.

Sockeye stock/timing group	'Recent Model Performance' Forecasts				
	Model	FOUR YEAR OLDS 50%[a]	FIVE YEAR OLDS 50%[a]	TOTAL 50%[a]	Age-4 Proportion
Early Stuart	*KF*	**42,000**	**2,000**	**44,000**	**95%**
Early Summer		**198,350**	**97,050**	**295,400**	
Bowron	*KF*	1,000	1,000	2,000	**50%**
Fennell	*Power*	4,000	8,000	12,000	**33%**
Gates	*KF*	11,000	1,000	12,000	**92%**
Nadina	*MRJ*	68,000	2,000	70,000	**97%**
Pitt	*KF*	3,000	32,000	35,000	**9%**
Raft	*Power*	19,000	22,000	41,000	**46%**
Scotch	*Larkin*	250	50	300	**83%**
Seymour	*Larkin*	2,000	2,500	4,500	**44%**
Misc [e]	*RS*	4,500	3,500	8,000	**56%**
Misc [f]	*RS*	1,000	1,000	2,000	**50%**
Misc [g]	*RS*	2,000	19,000	21,000	**10%**
Misc [h]	*RS*	82,000	2,000	84,000	**98%**
Misc [i]	*RS*	600	3,000	3,600	**17%**
Summer		**909,000**	**226,000**	**1,135,000**	
Chilko	*KF (juv)*	441,000	121,000	562,000	**78%**
Late Stuart	*RS4yr*	169,000	2,000	171,000	**99%**
Quesnel[b]	*RAC*	11,000	35,000	46,000	**24%**
Stellako[b]	*Larkin*	288,000	68,000	356,000	**81%**
Late		**47,600**	**147,200**	**194,800**	
Cultus	*Smolt-Jack(trunc)*	3,600	100	3,700	**97%**
Harrison[c]	*Ricker (Ei)*	26,000	28,000	54,000	**48%**
Late Shuswap	*Ricker (Pi)*	400	17,600	18,000	**2%**
Portage	*KF*	600	500	1,100	**55%**
Weaver	*MRS*	7,000	41,000	48,000	**15%**
Birkenhead	*RS4yr*	8,000	55,000	63,000	**13%**
Misc. non-Shuswap[l]	*RS*	2,000	5,000	7,000	**29%**
Total		**1,196,950**	**472,250**	**1,669,200**	**72%**

a. Probability that actual return will be at or below specified run size
b. Age compositions for Quesnel and Stellako are calculated using the proportions that would be applied by a biological mo
c. Harrison are age-4 (in four year old columns) and age-3 (in five year old columns) forecasts

Below subscripts line up with same subscripts in Tables 1 & 2
e. Unforecasted mis. Early Summer Stocks (Early Shuwap stocks: S.Thompson); return timing most similar to Scotch/Seyr
f. Unforecasted misc. Early Summer stocks (N. Thomson tributaries; return timing most similar to Raft/Fennell (Ra/Fe)).
g. North Thompson River
h. Chilliwack Lake and Dolly Varden Creek (Esum)
i. Nahatlach River & Lake (Esum)
l. Unforecasted miscellaneous Late Run stocks (Harrison L.)

Table A4. Performance measure calculations and rankings for the 'Recent Model Performance' scenario. For each stock performance measures were calculated by model using the recent jack-knife time-series (1997-2004). Model ranking by performance measure, and average rank across all four performance measures are shown. The last column for each stock indicated whether the model consistently ranks within the top half of models on every performance measure.

RUN-TIMING: EARLY STUART

Early Stuart	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	-0.228	0.228	-6.7619	0.241	17	17	20	16	17.5	17	NO
R1C	-0.261	0.262	-2.4718	0.528	19	19	17	20	18.75	19	NO
R2C	-0.333	0.333	-3.8297	0.508	20	20	19	19	19.5	20	NO
RAC	-0.237	0.24	-3.7216	0.35	18	18	18	18	18	18	NO
MRS	-0.121	0.121	-1.3652	0.168	10	10	8	10	9.5	10	YES
RS1	-0.036	0.048	-0.3115	0.086	5	5	5	5	5	5	YES
RS2	-0.025	0.028	-0.2168	0.048	4	4	4	4	4	4	YES
RSC	-0.141	0.141	-1.529	0.197	13	13	10	13	12.25	13	NO
RS4yr	-0.004	0.027	-0.1174	0.034	2	3	1	3	2.25	2	YES
RS8yr	-0.005	0.018	-0.1187	0.022	3	2	2	2	2.25	2	YES
Ricker	-0.13	0.13	-1.5798	0.176	11	11	13	11	11.5	11	NO
Ricker (FrD-mean)	-0.136	0.136	-1.5633	0.186	12	12	11	12	11.75	12	NO
Ricker (EI)	-0.093	0.095	-0.9732	0.136	6	6	6	7	6.25	6	YES
Ricker (PI)	-0.112	0.112	-1.1854	0.165	8	8	7	9	8	7	YES
Ricker (FrD-peak)	-0.149	0.149	-1.571	0.211	15	15	12	15	14.25	15	NO
Ricker (PDO)	-0.119	0.119	-1.5017	0.164	9	9	9	8	8.75	9	YES
Ricker cyc	-0.164	0.164	-1.9585	0.241	16	16	16	16	16	16	NO
Power	-0.097	0.097	-1.5991	0.114	7	7	14	6	8.5	8	NO
Larkin	-0.146	0.146	-1.7308	0.197	14	14	15	13	14	14	NO
KF	0.001	0.015	-0.1759	0.02	1	1	3	1	1.5	1	YES

RUN-TIMING: EARLY SUMMER

Bowron	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	-0.029	0.029	-4.7013	0.03	19	19	19	19	19	19	NO
R1C	-0.007	0.009	-1.767	0.012	2	2	5	2	2.75	3	YES
R2C	-0.009	0.011	-1.9072	0.014	3	4	6	4	4.25	4	YES
RAC	-0.03	0.03	-4.9334	0.039	20	20	20	20	20	20	NO
MRS	-0.016	0.016	-2.3061	0.019	8	7	9	7	7.75	7	YES
RS1	-0.014	0.018	-2.0625	0.024	6	9	7	17	9.75	10	NO
RS2	-0.014	0.015	-1.7536	0.018	6	6	4	6	5.5	6	YES
RSC	-0.018	0.019	-2.5175	0.022	10	11	12	13	11.5	11	NO
RS4yr	-0.009	0.009	-1.2687	0.013	3	2	2	3	2.5	2	YES
RS8yr	-0.012	0.012	-1.6363	0.014	5	5	3	4	4.25	4	YES
Ricker	-0.019	0.019	-2.7934	0.02	12	11	15	9	11.75	13	NO
Ricker (FrD-mean)	-0.02	0.02	-2.7426	0.022	16	16	13	13	14.5	16	NO
Ricker (EI)	-0.017	0.017	-2.3332	0.019	9	8	10	7	8.5	8	YES
Ricker (PI)	-0.018	0.018	-2.2963	0.02	10	9	8	9	9	9	YES
Ricker (FrD-peak)	-0.019	0.019	-2.7553	0.022	12	11	14	13	12.5	15	NO
Ricker (PDO)	-0.019	0.019	-2.505	0.021	12	11	11	12	11.5	11	NO
Ricker cyc	-0.021	0.021	-2.8762	0.025	18	18	18	18	18	18	NO
Power	-0.019	0.019	-2.7934	0.02	12	11	15	9	11.75	13	NO
Larkin	-0.02	0.02	-2.7957	0.022	16	16	17	13	15.5	17	NO
KF	-0.005	0.008	-1.0871	0.01	1	1	1	1	1	1	YES

Fennell	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	0.004	0.021	-0.6489	0.025	6	2	5	1	3.5	2	YES
R1C	0	0.029	-1.1641	0.037	1	17	10	18	11.5	12	NO
R2C	0.002	0.023	-0.8269	0.028	3	6	7	7	5.75	5	YES
RAC	0.004	0.019	-0.4778	0.026	6	1	3	3	3.25	1	YES
MRS	-0.014	0.027	-1.9062	0.032	15	13	16	13	14.25	16	NO
RS1	0.003	0.032	-1.1058	0.038	4	19	9	19	12.75	15	NO
RS2	0.008	0.026	-0.6165	0.033	9	11	4	15	9.75	10	NO
RSC	-0.019	0.032	-2.3477	0.038	19	19	20	19	19.25	20	NO
RS4yr	0.012	0.023	-0.2477	0.031	12	6	1	12	7.75	8	NO
RS8yr	0.012	0.021	-0.2492	0.029	12	2	2	8	6	6	NO
Ricker	-0.01	0.025	-1.4074	0.026	11	9	12	3	8.75	9	NO
Ricker (FrD-mean)	-0.012	0.026	-1.7421	0.029	12	11	15	8	11.5	12	NO
Ricker (EI)	-0.008	0.025	-1.4909	0.029	9	9	13	8	9.75	10	NO
Ricker (PI)	-0.015	0.028	-2.0115	0.034	17	15	17	17	16.5	17	NO
Ricker (FrD-peak)	-0.017	0.029	-2.1149	0.033	18	17	19	15	17.25	19	NO
Ricker (PDO)	-0.014	0.027	-1.7321	0.029	15	13	14	8	12.5	14	NO
Ricker cyc	-0.02	0.028	-2.055	0.032	20	15	18	13	16.5	17	NO
Power	0.001	0.022	-0.8782	0.026	2	4	8	3	4.25	3	YES
Larkin	-0.006	0.024	-1.2788	0.026	8	8	11	1	7	7	NO
KF	0.003	0.022	-0.7449	0.027	4	4	6	6	5	4	YES

Gates	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	-0.02	0.029	-3.0464	0.033	5	5	19	5	8.5	7	NO
R1C	-0.026	0.037	-2.0114	0.046	7	16	7	14	11	10	NO
R2C	-0.033	0.037	-2.0138	0.051	16	16	8	16	14	17	NO
RAC	-0.023	0.031	-1.1768	0.045	6	6	1	13	6.5	5	NO
MRS	-0.031	0.035	-2.6356	0.046	10	10	11	14	11.25	11	NO
RS1	-0.032	0.041	-4.023	0.059	13	19	20	19	17.75	19	NO
RS2	-0.029	0.038	-1.9739	0.063	9	18	5	20	13	15	NO
RSC	-0.038	0.043	-2.9113	0.057	20	20	18	18	19	20	NO
RS4yr	-0.011	0.019	-1.282	0.026	3	4	2	4	3.25	3	YES
RS8yr	-0.01	0.017	-1.3422	0.022	2	2	3	3	2.5	2	YES
Ricker	-0.032	0.035	-2.8695	0.042	13	10	17	8	12	13	NO
Ricker (FrD-mean)	-0.031	0.034	-2.8064	0.042	10	9	12	8	9.75	8	NO
Ricker (Ei)	-0.033	0.036	-2.8358	0.044	16	14	16	12	14.5	18	NO
Ricker (Pi)	-0.032	0.035	-2.8126	0.043	13	10	13	10	11.5	12	NO
Ricker (FrD-peak)	-0.031	0.033	-2.8248	0.039	10	8	15	6	9.75	8	NO
Ricker (PDO)	-0.033	0.035	-2.8168	0.043	16	10	14	10	12.5	14	NO
Ricker cyc	-0.033	0.036	-1.9684	0.052	16	14	6	17	13.25	16	NO
Power	-0.014	0.017	-2.0357	0.021	4	2	9	2	4.25	4	YES
Larkin	-0.026	0.032	-2.1235	0.039	7	7	10	6	7.5	6	YES
KF	-0.005	0.015	-1.5032	0.019	1	1	4	1	1.75	1	YES

Nadina	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	0.007	0.069	-5.0775	0.085	5	19	33	17	18.5	21	NO
R1C	-0.039	0.051	-1.255	0.083	24	4	19	15	15.5	18	NO
R2C	-0.027	0.046	-2.113	0.06	21	1	27	1	12.5	11	NO
RAC	0.006	0.057	-4.3286	0.07	2	7	32	6	11.75	10	NO
MRS	-0.022	0.07	-0.9809	0.095	17	20	2	20	14.75	17	NO
RS1	-0.203	0.254	-2.1627	0.511	32	32	29	32	31.25	32	NO
RS2	-0.258	0.286	-2.0412	0.633	33	33	26	33	31.25	32	NO
RSC	-0.093	0.123	-1.2688	0.233	29	29	20	29	26.75	29	NO
RS4yr	-0.021	0.082	-1.3236	0.109	16	24	21	23	21	23	NO
RS8yr	-0.024	0.076	-1.06	0.104	18	21	5	22	16.5	20	NO
Ricker	-0.019	0.068	-1.0972	0.087	15	18	6	18	14.25	16	NO
Ricker (FrD-mean)	-0.018	0.066	-1.1424	0.084	14	15	9	16	13.5	14	YES
Ricker (Ei)	-0.015	0.063	-1.177	0.079	9	12	11	10	10.5	7	YES
Ricker (Pi)	-0.015	0.065	-1.1094	0.082	9	13	8	12	10.5	7	YES
Ricker (FrD-peak)	-0.006	0.051	-1.1525	0.065	2	4	10	4	5	3	YES
Ricker (PDO)	-0.016	0.066	-1.1992	0.082	11	15	13	12	12.75	12	YES
Ricker cyc	-0.082	0.112	-1.3978	0.198	28	28	22	28	26.5	27	NO
Power	-0.024	0.076	-1.2363	0.101	18	21	17	21	19.25	22	NO
Larkin	-0.033	0.079	-1.477	0.146	23	23	24	26	24	24	NO
KF	0.006	0.053	-0.8006	0.065	2	6	1	4	3.25	2	YES
MRJ	-0.001	0.049	-0.9826	0.06	1	3	3	1	2	1	YES
RJ1	-0.141	0.186	-2.6429	0.344	31	31	31	31	31	31	NO
RJ2	-0.136	0.162	-2.158	0.32	30	30	28	30	29.5	30	NO
RJC	-0.028	0.067	-1.1062	0.094	22	17	7	19	16.25	19	NO
RJ4yr	-0.041	0.097	-2.5141	0.126	26	25	30	25	26.5	27	NO
RJ8yr	-0.04	0.097	-1.8632	0.116	25	25	25	24	24.75	25	NO
Power (juv)	-0.016	0.065	-1.2147	0.082	11	13	15	12	12.75	12	YES
Power (juv) (FrD-mean)	-0.049	0.102	-1.2525	0.157	27	27	18	27	24.75	25	NO
Power (juv) (Ei)	-0.018	0.062	-1.4286	0.079	11	10	23	10	13.5	14	NO
Power (juv) (Pi)	-0.009	0.058	-1.2021	0.074	6	8	14	7	8.75	5	YES
Power (juv) (FrD-peak)	-0.011	0.06	-1.1961	0.075	7	9	12	8	9	6	YES
Power (juv) (PDO)	-0.012	0.062	-1.2361	0.077	8	10	16	9	10.75	9	YES
KF (juv)	0.025	0.047	-0.9937	0.06	20	2	4	1	6.75	4	NO

Pitt	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	0.022	0.042	-0.1341	0.051	12	3	2	4	5.25	4	NO
R1C	-0.008	0.073	-0.9294	0.08	5	13	14	13	11.25	12	NO
R2C	0.016	0.065	-0.4130	0.07	9	11	7	11	9.5	11	NO
RAC	0.033	0.046	-0.1640	0.054	13	5	3	5	6.5	6	NO
MRS	-0.108	0.125	-2.4026	0.157	15	15	15	15	15	15	NO
RS1	-0.229	0.229	-3.4118	0.250	20	20	18	18	19	20	NO
RS2	-0.19	0.193	-4.3882	0.259	18	18	20	19	18.75	18	NO
RSC	-0.112	0.13	-2.8487	0.169	16	16	16	16	16	16	NO
RS4yr	-0.209	0.21	-3.1636	0.267	19	19	17	20	18.75	18	NO
RS8yr	-0.169	0.186	-3.8019	0.244	17	17	18	17	17.5	17	NO
Ricker	0.017	0.05	-0.3094	0.065	11	6	4	6	6.75	7	NO
Ricker (FtD-mean)	-0.016	0.067	-0.8631	0.072	9	12	13	12	11.5	13	NO
Ricker (EI)	0.01	0.043	-0.3358	0.047	6	4	5	2	4.25	3	YES
Ricker (PI)	0.006	0.059	-0.5282	0.062	3	10	9	10	8	9	YES
Ricker (FtD-peak)	-0.007	0.051	-0.729	0.06	4	8	12	8	8	9	NO
Ricker (PDO)	0.005	0.05	-0.5448	0.057	2	6	10	7	6.25	5	YES
Ricker cyc	-0.015	0.077	-0.6922	0.102	8	14	11	14	11.75	14	NO
Power	0.013	0.054	-0.4044	0.06	7	9	6	8	7.5	8	YES
Larkin	0.025	0.034	0.105	0.045	14	1	1	1	4.25	2	NO
KF	0.001	0.035	-0.4516	0.048	1	2	8	3	3.5	1	YES

Raft	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	0.026	0.028	0.2548	0.046	12	6	4	15	9.75	11	NO
R1C	0.002	0.032	-0.1221	0.042	2	13	2	12	7.25	7	NO
R2C	0.012	0.035	0.083	0.041	4	15	1	11	7.75	8	NO
RAC	0.027	0.03	0.3679	0.042	14	12	8	12	11.5	13	NO
MRS	-0.029	0.034	-0.567	0.045	15	14	15	14	14.5	15	NO
RS1	-0.073	0.075	-1.6516	0.094	19	19	20	19	19.25	19	NO
RS2	-0.063	0.063	-1.4102	0.083	16	18	19	17	18	18	NO
RSC	-0.037	0.043	-0.6363	0.057	16	16	16	16	16	16	NO
RS4yr	-0.084	0.087	-1.2844	0.123	20	20	18	20	19.5	20	NO
RS8yr	-0.062	0.062	-1.1421	0.087	17	17	17	18	17.25	17	NO
Ricker	-0.02	0.028	-0.5081	0.038	8	8	11	8	8.75	10	NO
Ricker (FtD-mean)	-0.026	0.029	-0.5089	0.039	12	11	13	10	11.5	13	NO
Ricker (EI)	-0.024	0.026	-0.5096	0.037	10	5	10	7	8	9	YES
Ricker (PI)	-0.02	0.024	-0.4236	0.033	8	4	9	4	6.25	5	YES
Ricker (FtD-peak)	-0.025	0.028	-0.5293	0.038	11	8	14	8	10.25	12	NO
Ricker (PDO)	-0.016	0.023	-0.3369	0.035	6	3	6	6	5.25	4	YES
Ricker cyc	-0.014	0.019	-0.3622	0.025	5	1	7	1	3.5	2	YES
Power	0	0.019	-0.1475	0.025	1	1	3	1	1.5	1	YES
Larkin	-0.006	0.026	-0.2776	0.031	3	5	5	3	4	3	YES
KF	-0.017	0.026	-0.5085	0.033	7	5	12	4	7	6	NO

Scotch	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	0.036	0.144	-7.7089	0.229	3	20	20	20	15.75	19	NO
R1C	0.083	0.077	-1.4799	0.173	14	10	19	12	13.75	17	NO
R2C	0.057	0.08	-0.9699	0.175	11	12	16	14	13.25	16	NO
RAC	0.045	0.083	-1.0841	0.171	7	15	18	11	12.75	15	NO
MRS	0.05	0.066	-0.5696	0.125	8	8	14	6	9.25	6	NO
RS1	0.029	0.051	-0.5867	0.074	2	3	15	2	5.5	4	NO
RS2	0.045	0.058	-0.1399	0.105	7	4	6	4	5.25	3	YES
RSC	-0.012	0.028	-1.0317	0.039	1	1	17	1	5	2	NO
RS4yr	0.081	0.09	-0.0135	0.175	16	16	1	14	12.25	13	NO
RS8yr	0.086	0.09	0.0552	0.187	19	18	4	17	14	18	NO
Ricker	0.065	0.061	-0.2307	0.128	10	6	12	7	8.75	6	NO
Ricker (FtD-mean)	0.057	0.061	-0.1673	0.132	11	6	11	8	9	7	NO
Ricker (EI)	0.079	0.082	-0.0431	0.186	17	14	3	16	12.5	14	NO
Ricker (PI)	0.088	0.09	0.1694	0.189	20	16	10	19	16.25	20	NO
Ricker (FtD-peak)	0.062	0.067	-0.1636	0.146	13	9	9	9	10	9	NO
Ricker (PDO)	-0.036	0.091	0.0244	0.186	5	19	2	18	11	11	NO
Ricker cyc	0.037	0.06	-0.4069	0.124	4	5	13	5	6.75	5	NO
Power	0.076	0.08	-0.1431	0.173	16	12	7	12	11.75	12	NO
Larkin	0.041	0.042	0.1572	0.091	6	2	8	3	4.75	1	YES
KF	0.073	0.078	-0.1165	0.169	15	11	5	10	10.25	10	NO

Seymour	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	-0.014	0.127	-5.6414	0.162	7	20	20	20	16.75	19	NO
R1C	0.033	0.075	-1.5914	0.115	14	13	16	14	14.25	18	NO
R2C	0.033	0.068	-1.1512	0.116	14	7	10	15	11.5	14	NO
RAC	-0.013	0.08	-1.7746	0.104	6	14	18	10	12	15	NO
MRS	0.002	0.057	-1.4027	0.079	1	2	14	3	5	2	NO
RS1	-0.054	0.104	-2.5383	0.159	20	19	19	19	19.25	20	NO
RS2	-0.002	0.071	-0.9469	0.095	1	8	6	6	5.25	3	**YES**
RSC	-0.032	0.058	-1.6386	0.088	12	4	17	4	9.25	8	NO
RS4yr	0.033	0.073	-0.807	0.097	14	10	5	7	9	7	NO
RS8yr	0.053	0.08	-0.3811	0.113	18	14	1	12	11.25	13	NO
Ricker	0.009	0.063	-1.3725	0.09	4	6	13	5	7	6	NO
Ricker (FrD-mean)	0.016	0.074	-1.3384	0.102	8	12	12	9	10.25	9	NO
Ricker (Ei)	0.053	0.08	-0.5828	0.146	18	14	2	18	13	16	NO
Ricker (Pi)	0.031	0.062	-0.6166	0.098	11	5	3	8	6.75	5	NO
Ricker (FrD-peak)	0.024	0.08	-1.151	0.113	9	14	9	12	11	11	NO
Ricker (PDO)	0.032	0.072	-0.9701	0.126	12	9	7	16	11	11	NO
Ricker cyc	-0.011	0.046	-1.4329	0.07	5	1	15	1	5.5	4	NO
Power	0.024	0.073	-1.2734	0.106	9	10	11	11	10.25	9	NO
Larkin	0.006	0.057	-1.1246	0.078	3	2	8	2	3.75	1	**YES**
KF	0.05	0.086	-0.7231	0.131	17	18	4	17	14	17	NO

RUN-TIMING: SUMMER

Chilko	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	-0.494	0.371	-0.6826	0.519	13	9	14	10	11.5	13	**YES**
R1C	-0.103	0.47	-0.4702	0.628	3	12	8	14	9.25	10	**YES**
R2C	-0.684	0.513	-0.8015	0.714	16	15	15	17	15.75	16	NO
RAC	-0.35	0.36	-0.6631	0.609	9	7	13	12	10.25	11	**YES**
MRS	-1.436	1.077	-1.7631	1.373	32	32	32	32	32	32	NO
RS1	0.225	0.516	-0.1067	0.624	5	16	2	13	9	7	**YES**
RS2	-0.229	0.47	-0.4597	0.554	6	12	7	11	9	7	**YES**
RSC	-1.771	1.328	-2.1312	1.63	33	33	33	33	33	33	NO
RS4yr	0.303	0.286	0.1539	0.403	7	3	3	5	4.5	3	**YES**
RS8yr	-0.089	0.269	-0.2634	0.343	2	2	4	2	2.5	2	**YES**
Ricker	-0.83	0.623	-1.0382	0.783	23	23	22	21	22.25	23	NO
Ricker (FrD-mean)	-0.75	0.563	-0.954	0.721	20	20	19	18	19.25	18	NO
Ricker (Ei)	-1.145	0.859	-1.353	1.036	30	30	30	29	29.75	30	NO
Ricker (Pi)	-0.88	0.66	-1.1204	0.845	24	24	25	23	24	24	NO
Ricker (FrD-peak)	-1.022	0.767	-1.2335	0.94	28	28	28	27	27.75	28	NO
Ricker (PDO)	-0.79	0.592	-1.0093	0.761	21	21	21	20	20.75	21	NO
Ricker cyc	-0.946	0.71	-1.1889	0.896	26	28	27	26	26.25	26	NO
Power	-0.74	0.555	-0.9693	0.752	19	19	20	19	19.25	18	NO
Larkin	-0.718	0.538	-1.0603	0.828	17	17	23	22	19.75	20	NO
KF	-0.196	0.33	-0.4153	0.433	4	5	5	7	5.25	5	**YES**
MRJ	-1.139	0.855	-1.2854	1.087	29	29	29	30	29.25	29	NO
RJ1	-0.474	0.494	-0.8021	0.697	11	14	16	15	14	15	**YES**
RJ2	-0.822	0.616	-0.8403	0.887	22	22	18	25	21.75	22	NO
RJC	-1.243	0.932	-1.4316	1.121	31	31	31	31	31	31	NO
RJ4yr	-0.341	0.286	-0.4463	0.385	8	3	6	3	5	4	**YES**
RJ8yr	-0.732	0.549	-0.8213	0.71	18	18	17	16	17.25	17	NO
Power (juv)	-0.533	0.4	-0.5654	0.463	14	10	11	8	10.75	12	**YES**
Power (juv) (FrD-mean)	-0.914	0.685	-1.0799	0.877	25	25	24	24	24.5	25	NO
Power (juv) (Ei)	-0.983	0.738	-1.155	0.943	27	27	26	28	27	27	NO
Power (juv) (Pi)	-0.444	0.333	-0.4876	0.388	10	6	9	4	7.25	6	**YES**
Power (juv) (FrD-peak)	-0.562	0.421	-0.5978	0.488	15	11	12	9	11.75	14	**YES**
Power (juv) (PDO)	-0.485	0.364	-0.5274	0.423	12	8	10	6	9	7	**YES**
KF (juv)	0.04	0.202	-0.0913	0.252	1	1	1	1	1	1	**YES**

Late Stuart	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	-0.215	0.295	-4.3066	0.338	2	5	20	1	7	7	NO
R1C	-0.483	0.499	-1.7271	0.984	7	7	6	7	6.75	6	**YES**
R2C	-0.734	0.837	-2.2229	1.416	9	11	9	16	11.25	11	NO
RAC	-0.221	0.477	-0.8729	0.729	3	6	2	6	4.25	3	**YES**
MRS	-1.074	1.074	-3.5377	1.55	19	19	15	18	17.75	19	NO
RS1	-0.991	1.045	-1.6158	2.355	15	18	4	20	14.25	15	NO
RS2	-0.772	0.802	-1.6932	1.359	10	9	5	15	9.75	9	NO
RSC	-1.292	1.292	-3.7724	1.803	20	20	16	19	18.75	20	NO
RS4yr	-0.251	0.276	-0.7829	0.411	4	1	1	5	2.75	1	**YES**
RS8yr	-0.569	0.589	-1.5812	1.192	8	8	3	12	7.75	8	NO
Ricker	-0.288	0.288	-1.8844	0.382	5	3	7	3	4.5	4	NO
Ricker (FrD-mean)	-0.903	0.903	-3.8917	1.152	14	14	17	11	14	14	NO
Ricker (Ei)	-0.993	0.993	-4.1659	1.292	17	16	19	13	16.25	17	NO
Ricker (Pi)	-1.035	1.035	-3.4121	1.526	18	17	13	17	16.25	17	NO
Ricker (FrD-peak)	-0.991	0.991	-4.0444	1.324	15	15	18	14	15.5	16	NO
Ricker (PDO)	-0.862	0.862	-3.3615	1.091	13	13	12	8	11.5	12	NO
Ricker cyc	-0.829	0.829	-3.0761	1.14	11	10	11	10	10.5	10	**YES**
Power	-0.288	0.288	-1.8844	0.382	5	3	7	3	4.5	4	**YES**
Larkin	-0.842	0.842	-3.4358	1.128	12	12	14	9	11.75	13	NO
KF	-0.096	0.285	-2.2469	0.357	1	2	10	2	3.75	2	**YES**

Quesnel	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	0.46	1.719	-4.3427	1.99	2	7	11	5	6.25	6	NO
R1C	-0.632	1.332	-1.7374	1.831	5	4	5	4	4.5	4	YES
R2C	-0.87	1.49	-1.2357	2.011	6	5	3	6	5	5	YES
RAC	0.509	0.785	0.2446	1.466	4	1	1	1	1.75	1	YES
MRS	-4.891	4.891	-8.4164	7.259	19	19	19	19	19	19	NO
RS1	-1.894	2.431	-5.2335	4.087	10	17	15	14	14	15	NO
RS2	-2.066	2.071	-4.1869	3.577	13	11	10	11	11.25	10	NO
RSC	-6.579	6.579	-11.107	9.709	20	20	20	20	20	20	NO
RS4yr	-1.24	1.704	-3.4441	2.789	7	6	7	8	7	7	YES
RS8yr	-1.7	1.86	-3.2553	2.831	8	8	6	9	7.75	8	YES
Ricker	-2.152	2.152	-5.863	4.313	15	13	17	16	15.25	16	NO
Ricker (FrD-mean)	-2.017	2.072	-5.5546	4.104	12	12	16	15	13.75	13	NO
Ricker (EI)	-1.928	1.928	-3.4472	2.546	11	9	8	7	8.75	9	NO
Ricker (PI)	-2.172	2.172	-4.7472	3.659	16	14	12	13	13.75	13	NO
Ricker (FrD-peak)	-2.219	2.398	-6.2495	4.623	17	16	18	18	17.25	18	NO
Ricker (PDO)	-1.864	2.065	-5.1876	3.636	9	10	14	12	11.25	10	NO
Ricker cyc	-2.134	2.208	-3.9753	3.261	14	15	9	10	12	12	NO
Power	-2.518	2.666	-5.1334	4.414	18	18	13	17	16.5	17	NO
Larkin	-0.482	0.867	-1.4259	1.739	3	2	4	3	3	3	YES
KF	0.361	1.202	-1.0463	1.562	1	3	2	2	2	2	YES

Stellako	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	-0.147	0.221	-1.35	0.238	4	6	6	4	5	5	YES
R1C	-0.135	0.168	-0.8179	0.223	3	3	1	3	2.5	3	YES
R2C	-0.191	0.204	-0.951	0.256	6	4	4	5	4.75	4	YES
RAC	-0.154	0.211	-1.5959	0.281	5	5	8	7	6.25	6	YES
MRS	-0.541	0.541	-2.782	0.621	19	19	19	19	19	19	NO
RS1	-0.276	0.289	-1.4156	0.346	11	13	7	15	11.5	12	NO
RS2	-0.439	0.444	-1.9473	0.513	18	18	17	18	17.75	18	NO
RSC	-0.619	0.619	-3.1397	0.716	20	20	20	20	20	20	NO
RS4yr	-0.24	0.243	-1.2274	0.269	7	7	5	6	6.25	6	YES
RS8yr	-0.364	0.364	-1.7433	0.416	16	16	10	16	14.5	15	NO
Ricker	-0.269	0.28	-1.8161	0.324	9	10	13	10	10.5	10	NO
Ricker (FrD-mean)	-0.279	0.279	-1.7844	0.311	12	9	11	9	10.25	9	NO
Ricker (EI)	-0.267	0.267	-1.7241	0.297	8	8	9	8	8.25	8	YES
Ricker (PI)	-0.299	0.299	-1.8215	0.341	15	15	15	14	14.75	16	NO
Ricker (FrD-peak)	-0.289	0.289	-1.8344	0.324	14	13	16	10	13.25	14	NO
Ricker (PDO)	-0.282	0.282	-1.8041	0.334	13	12	12	13	12.5	13	NO
Ricker cyc	-0.394	0.394	-2.1916	0.508	17	17	18	17	17.25	17	NO
Power	-0.269	0.28	-1.8161	0.324	9	10	13	10	10.5	10	NO
Larkin	-0.104	0.13	-0.8218	0.151	2	1	2	1	1.5	1	YES
KF	-0.065	0.165	-0.9453	0.19	1	2	3	2	2	2	YES

RUN-TIMING: LATE

Cultus	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	-0.04	0.04	-39921	0.04	14	14	14	13	13.75	14	NO
R1C	-0.002	0.002	-2334.4	0.003	2	2	3	2	2.25	3	YES
R2C	-0.003	0.003	-3351.8	0.004	4	4	6	4	4.5	6	YES
RAC	-0.038	0.038	-37913	0.047	13	13	13	14	13.25	13	NO
MRJ	-0.003	0.003	-3279	0.004	4	4	5	4	4.25	5	YES
RJ1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
RJ2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
RJC	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
RJ4yr	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
RJ8yr	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Power (juv)	-0.004	0.004	-3646.8	0.004	8	8	10	4	7.5	9	NO
Power (juv) (FrD-mean)	-0.004	0.004	-3742	0.004	8	8	12	4	8	11	NO
Power (juv) (EI)	-0.003	0.003	-3470.8	0.004	4	4	7	4	4.75	7	YES
Power (juv) (PI)	-0.004	0.004	-3641	0.004	8	8	9	4	7.25	8	NO
Power (juv) (FrD-peak)	-0.004	0.004	-3692.8	0.004	8	8	11	4	7.75	10	NO
Power (juv) (PDO)	-0.003	0.003	-3092.8	0.004	4	4	4	4	4	4	YES
KF	-0.002	0.002	-2264.8	0.003	2	2	2	2	2	2	YES
Smolt Jack(Trunc)	-0.001	0.001	-1421.9	0.002	1	1	1	1	1	1	YES
Smolt-Jack(Full)	-0.004	0.004	-3508.4	0.005	8	8	8	12	9	12	NO

Harrison	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	0.09	0.094	0.3586	0.152	4	5	1	10	5	4	NO
R1C	0.096	0.1	0.5436	0.139	8	9	6	8	7.75	8	YES
R2C	0.102	0.102	0.5594	0.154	11	11	7	11	10	10	NO
RAC	0.095	0.095	0.4869	0.154	7	7	5	11	7.5	7	NO
MRS	-0.11	0.298	-4.4465	0.582	15	14	15	14	14.5	15	NO
RS1	-1.248	1.321	-30.135	3.46	18	18	18	18	18	18	NO
RS2	-1.497	1.632	-38.101	4.425	19	19	19	19	19	19	NO
RSC	-0.106	0.301	-4.4217	0.582	13	15	14	14	14	14	NO
RS4yr	-0.34	0.472	-9.5177	1.152	17	17	17	17	17	17	NO
RS8yr	-0.246	0.409	-7.5737	0.935	16	16	16	16	16	16	NO
Ricker	0.098	0.098	0.6492	0.133	9	8	11	6	8.5	9	NO
Ricker (FrD-mean)	0.094	0.094	0.6103	0.129	6	5	10	5	7	6	NO
Ricker (EI)	0.06	0.068	0.4686	0.089	1	1	2	1	1	1	YES
Ricker (PI)	0.092	0.092	0.6057	0.124	5	4	9	4	6	5	YES
Ricker (FrD-peak)	0.084	0.085	0.4843	0.121	3	3	4	3	3	3	YES
Ricker (PDO)	0.103	0.103	0.6631	0.14	12	12	12	9	11	12	NO
Power	0.109	0.109	0.6012	0.159	14	13	8	13	12	13	NO
Larkin	0.101	0.101	0.6701	0.136	10	10	13	7	10	10	NO
KF	0.078	0.078	0.4795	0.113	2	2	3	2	2	2	YES

Late Shuswap	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	-0.244	2.832	-83.138	3.147	7	17	20	14	14.5	15	NO
R1C	0.518	0.691	-1.5922	1.623	10	3	2	4	4.75	4	YES
R2C	0.475	0.678	-1.3432	1.167	9	2	1	2	3.5	2	YES
RAC	-0.222	0.324	-1.7102	0.564	6	1	3	1	2.75	1	YES
MRS	-1.598	2.269	-3.7214	4.44	17	16	15	17	16.25	17	NO
RS1	-2.361	3.539	-5.2862	7.463	19	19	18	19	18.75	19	NO
RS2	-0.86	2.049	-3.2829	3.795	15	14	11	15	13.75	14	NO
RSC	-1.43	2.23	-3.8759	4.232	16	15	16	16	15.75	16	NO
RS4yr	-3.799	4.743	-6.5406	10.27	20	20	19	20	19.75	20	NO
RS8yr	-1.896	2.9	-4.4625	5.695	18	18	17	18	17.75	18	NO
Ricker	-0.207	1.269	-3.55	1.961	5	9	14	8	9	9	NO
Ricker (FrD-mean)	0.104	1.026	-3.2261	1.865	3	6	10	7	6.5	6	YES
Ricker (EI)	0.719	1.351	-1.7935	2.155	13	11	4	11	9.75	11	NO
Ricker (PI)	0.167	0.878	-2.205	1.586	4	4	7	3	4.5	3	YES
Ricker (FrD-peak)	0.011	1.004	-3.0853	1.738	1	5	9	5	5	5	YES
Ricker (PDO)	0.061	1.074	-3.2844	1.738	2	7	12	5	6.5	6	NO
Ricker cyc	-0.6	1.199	-1.9157	2.1	12	8	6	9	8.75	8	NO
Power	-0.433	1.524	-3.386	2.324	8	12	13	12	11.25	12	NO
Larkin	0.569	1.324	-1.8801	2.116	11	10	5	10	9	9	NO
KF	0.75	1.532	-2.3848	2.42	14	13	8	13	12	13	NO

Portage	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	-0.025	0.026	-3.1165	0.03	3	3	13	2	5.25	4	NO
R1C	-0.043	0.051	-2.6054	0.068	17	18	8	17	15	17	NO
R2C	-0.056	0.056	-3.6748	0.068	20	19	20	17	19	19	NO
RAC	-0.026	0.026	-2.0562	0.031	4	3	1	4	3	3	YES
MRS	-0.047	0.047	-3.4678	0.069	18	17	18	19	18	18	NO
RS1	-0.063	0.063	-3.4694	0.127	19	20	19	20	19.5	20	NO
RS2	-0.036	0.036	-2.2958	0.06	14	14	5	15	12	13	NO
RSC	-0.039	0.039	-3.2241	0.052	15	15	16	12	14.5	15	NO
RS4yr	-0.03	0.031	-2.2281	0.06	6	7	4	15	8	8	NO
RS8yr	-0.032	0.033	-2.407	0.051	8	9	6	11	8.5	9	NO
Ricker	-0.03	0.03	-2.955	0.037	6	6	10	5	6.75	6	YES
Ricker (FrD-mean)	-0.035	0.035	-3.0571	0.044	10	10	11	9	10	10	NO
Ricker (EI)	-0.026	0.029	-2.4489	0.042	4	5	7	6	5.5	5	YES
Ricker (PI)	-0.039	0.039	-3.1934	0.056	15	15	15	13	14.5	15	NO
Ricker (FrD-peak)	-0.035	0.035	-3.123	0.045	10	10	14	10	11	12	NO
Ricker (PDO)	-0.035	0.035	-3.284	0.058	10	10	17	14	12.75	14	NO
Ricker cyc	-0.035	0.035	-3.0738	0.043	10	10	12	8	10	10	NO
Power	-0.021	0.021	-2.1398	0.03	2	2	3	2	2.25	2	YES
Larkin	-0.032	0.032	-2.6314	0.042	8	8	9	6	7.75	7	YES
KF	-0.017	0.018	-2.0747	0.025	1	1	2	1	1.25	1	YES

Weaver	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	-0.145	0.184	-0.9829	0.191	28	23	31	17	24.75	29	NO
R1C	-0.159	0.161	-0.7334	0.193	29	18	26	19	23	24	NO
R2C	-0.226	0.249	-1.1644	0.279	33	32	33	32	32.5	32	NO
RAC	-0.161	0.173	-0.8919	0.202	30	22	29	21	25.5	30	NO
MRS	-0.025	0.113	-0.2472	0.135	7	5	9	5	6.5	2	**YES**
RS1	-0.161	0.185	-0.9741	0.242	30	25	30	26	27.75	31	NO
RS2	-0.218	0.252	-0.986	0.311	32	33	32	33	32.5	32	NO
RSC	-0.028	0.123	-0.264	0.142	11	9	10	7	9.25	7	**YES**
RS4yr	-0.123	0.154	-0.7633	0.214	26	17	28	23	23.5	25	NO
RS8yr	-0.134	0.163	-0.7526	0.212	27	19	27	22	23.75	27	NO
Ricker	-0.054	0.122	-0.4264	0.155	21	8	23	9	15.25	14	NO
Ricker (FrD-mean)	-0.027	0.113	-0.305	0.136	9	5	13	6	8.25	5	**YES**
Ricker (EI)	-0.05	0.12	-0.4068	0.152	20	7	21	8	14	13	NO
Ricker (PI)	-0.04	0.104	-0.328	0.125	16	4	16	4	10	9	**YES**
Ricker (FrD-peak)	-0.034	0.097	-0.2993	0.119	14	2	12	2	7.5	3	**YES**
Ricker (PDO)	-0.027	0.097	-0.2221	0.115	9	2	7	1	4.75	1	**YES**
Ricker cyc	-0.079	0.133	-0.5367	0.174	24	11	24	14	18.25	20	NO
Power	-0.044	0.094	-0.4159	0.121	18	1	22	3	11	11	NO
Larkin	-0.079	0.125	-0.5994	0.173	24	10	25	13	18	19	NO
KF	0.029	0.184	-0.0291	0.225	13	23	1	24	15.25	14	NO
MRJ	-0.018	0.198	-0.2442	0.237	6	26	8	25	16.25	17	NO
RJ1	-0.045	0.214	-0.3291	0.243	19	30	18	27	23.5	25	NO
RJ2	-0.028	0.203	-0.3111	0.259	11	27	15	29	20.5	22	NO
RJC	-0.025	0.207	-0.2853	0.26	7	28	11	30	19	21	NO
RJ4yr	-0.035	0.208	-0.3281	0.247	15	29	17	28	22.25	23	NO
RJ8yr	-0.041	0.223	-0.3659	0.26	17	31	20	30	24.5	28	NO
Power (juv)	0.059	0.15	0.3101	0.162	22	15	14	10	15.25	14	NO
Power (juv) (FrD-mean)	0.07	0.148	0.3491	0.163	23	13	19	11	16.5	18	NO
Power (juv) (EI)	0.003	0.148	-0.074	0.176	2	13	4	15	8.5	6	**YES**
Power (juv) (PI)	-0.002	0.153	-0.0983	0.18	1	16	5	16	9.5	8	**YES**
Power (juv) (FrD-peak)	0.007	0.141	-0.0506	0.17	3	12	3	12	7.5	3	**YES**
Power (juv) (PDO)	-0.015	0.163	-0.1317	0.194	4	19	6	20	12.25	12	NO
KF (juv)	0.015	0.163	-0.0384	0.192	4	19	2	18	10.75	10	NO

Birkenhead	MRE	MAE	MPE	RMSE	MRE Rank	MAE Rank	MPE Rank	RMSE Rank	Average	Overall Rank	Consistently Top Half?
TSA	-0.136	0.219	-2.0292	0.23	11	12	14	7	11	11	NO
R1C	0.006	0.183	-0.5745	0.216	2	3	2	5	3	3	**YES**
R2C	-0.077	0.229	-1.943	0.347	7	13	10	17	11.75	13	NO
RAC	-0.141	0.195	-1.757	0.204	13	6	8	2	7.25	7	NO
MRS	-0.4	0.4	-3.455	0.555	19	19	19	19	19	19	NO
RS1	-0.017	0.158	-0.7861	0.199	3	1	3	1	2	2	**YES**
RS2	-0.063	0.251	-1.4865	0.283	6	17	6	15	11	11	NO
RSC	-0.476	0.476	-4.114	0.65	20	20	20	20	20	20	NO
RS4yr	0.005	0.169	-0.5729	0.207	1	2	1	3	1.75	1	**YES**
RS8yr	-0.038	0.191	-0.8555	0.227	5	5	4	6	5	4	**YES**
Ricker	-0.135	0.211	-1.9646	0.246	10	9	12	11	10.5	9	NO
Ricker (FrD-mean)	-0.141	0.23	-2.0695	0.275	13	14	15	13	13.75	15	NO
Ricker (EI)	-0.087	0.188	-1.5816	0.215	8	4	7	4	5.75	5	**YES**
Ricker (PI)	-0.127	0.201	-1.8121	0.236	9	8	9	8	8.5	8	**YES**
Ricker (FrD-peak)	-0.204	0.241	-2.5471	0.329	17	16	18	16	16.75	17	NO
Ricker (PDO)	-0.159	0.23	-2.2667	0.279	15	14	17	14	15	16	NO
Ricker cyc	-0.264	0.277	-2.1349	0.355	18	18	16	18	17.5	18	NO
Power	-0.138	0.215	-1.9581	0.241	12	11	11	9	10.75	10	NO
Larkin	-0.159	0.212	-1.9955	0.248	15	10	13	12	12.5	14	NO
KF	0.033	0.199	-0.8598	0.244	4	7	5	10	6.5	6	**YES**

Table A5. Top three ranked model forecasts evaluated for each stock for the 'Recent Model Performance' sensitivity analysis, determined by average rank across Performance Measures (MAE, MPE, MRE and RMSE).

RUN TIMING GROUP: EARLY STUART

EARLY STUART	Rank	Return Forecast 10%	25%	50%	75%	90%
KF	**1**	**17,000**	**27,000**	**44,000**	**73,000**	**122,000**
RS8yr	2	14,000	23,000	38,000	64,000	102,000
RS4yr	2	13,000	21,000	36,000	62,000	99,000

RUN TIMING GROUP: EARLY SUMMER

BOWRON	Rank	Return Forecast 10%	25%	50%	75%	90%
KF	**1**	**1,000**	**1,000**	**2,000**	**4,000**	**6,000**
RS4yr	2	0	1,000	1,000	2,000	4,000
R1C	3	1,000	2,000	3,000	6,000	12,000

FENNELL	Rank	Return Forecast 10%	25%	50%	75%	90%
RAC	1	11,000	19,000	34,000	62,000	105,000
TSA	2	9,000	15,000	25,000	42,000	67,000
Power	**3**	**5,000**	**7,000**	**12,000**	**20,000**	**32,000**

GATES	Rank	Return Forecast 10%	25%	50%	75%	90%
KF	1	**4,000**	**6,000**	**12,000**	**21,000**	**36,000**
RS8yr	2	3,000	6,000	11,000	20,000	34,000
RS4yr	3	3,000	5,000	10,000	19,000	35,000

NADINA	Rank	Return Forecast 10%	25%	50%	75%	90%
MRJ	**1**	**17,000**	**33,000**	**70,000**	**147,000**	**289,000**
KF	2	18,000	30,000	55,000	101,000	189,000
Ricker (FrD-peak)	3	30,000	47,000	91,000	153,000	274,000

PITT	Rank	Return Forecast 10%	25%	50%	75%	90%
KF	**1**	**11,000**	**18,000**	**35,000**	**65,000**	**110,000**
Larkin	2	19,000	29,000	45,000	71,000	110,000
Ricker (Ei)	2	31,000	45,000	73,000	125,000	200,000

RAFT	Rank	Return Forecast 10%	25%	50%	75%	90%
Power	**1**	**18,000**	**27,000**	**41,000**	**62,000**	**91,000**
Ricker-cyc	2	30,000	44,000	67,000	108,000	167,000
Larkin	3	17,000	26,000	37,000	59,000	90,000

SCOTCH	Rank	Return Forecast 10%	25%	50%	75%	90%
Larkin	**1**	**100**	**200**	**300**	**700**	**1,400**
RSC	2	800	2,000	4,000	10,000	23,000
RS2	3	600	1,000	3,000	9,000	20,000

SEYMOUR	Rank	Return Forecast 10%	25%	50%	75%	90%
Larkin	**1**	**1,000**	**3,000**	**5,000**	**8,000**	**15,000**
MRS	2	2,000	3,000	7,000	14,000	25,000
RS2	3	1,000	2,000	4,000	8,000	16,000

RUN TIMING GROUP: SUMMER

CHILKO	Rank	Return Forecast 10%	25%	50%	75%	90%
KF (juv)	**1**	**229,000**	**342,000**	**562,000**	**868,000**	**1,274,000**
RS8yr	2	45,000	88,000	183,000	381,000	736,000
RS4yr	3	65,000	124,000	256,000	527,000	1,008,000

LATE STUART	Rank	Return Forecast 10%	25%	50%	75%	90%
RS4yr	**1**	**22,000**	**59,000**	**171,000**	**500,000**	**1,311,000**
KF	2	40,000	94,000	245,000	708,000	1,524,000
RAC	3	32,000	74,000	185,000	463,000	1,058,000

QUESNEL	Rank	Return Forecast 10%	25%	50%	75%	90%
RAC	**1**	**5,000**	**15,000**	**46,000**	**144,000**	**403,000**
KF	2	3,000	5,000	11,000	22,000	47,000
Larkin	3	16,000	28,000	50,000	94,000	185,000

STELLAKO	Rank	Return Forecast 10%	25%	50%	75%	90%
Larkin	**1**	**189,000**	**251,000**	**356,000**	**519,000**	**752,000**
KF	2	94,000	146,000	223,000	349,000	542,000
R1C	3	94,000	143,000	228,000	364,000	555,000

RUN TIMING GROUP: LATE

CULTUS	Rank	Return Forecast 10%	25%	50%	75%	90%
Smolt-Jack (trunc)	1	**2,000**	**2,000**	**4,000**	**5,000**	**7,000**
KF (juv)	2	700	1,000	3,000	7,000	15,000
R1C	3	200	400	1,000	3,000	8,000

HARRISON	Rank	Return Forecast 10%	25%	50%	75%	90%
Ricker (Ei)	**1**	**12,000**	**26,000**	**54,000**	**114,000**	**235,000**
KF	2	20,000	39,000	83,000	184,000	401,000
Ricker (FrD-peak)	3	12,000	25,000	56,000	161,000	357,000

LATE SHUSWAP	Rank	Return Forecast 10%	25%	50%	75%	90%
RAC	1	6,000	13,000	28,000	63,000	132,000
R2C	2	3,000	7,000	17,000	43,000	98,000
Ricker (Pi)	**3**	**1,000**	**2,000**	**18,000**	**134,000**	**371,000**

PORTAGE	Rank	Return Forecast 10%	25%	50%	75%	90%
KF	**1**	**200**	**500**	**1,000**	**3,000**	**5,000**
Power	2	1,000	2,000	4,000	7,000	14,000
RAC	3	3,000	7,000	15,000	32,000	65,000

WEAVER	Rank	Return Forecast 10%	25%	50%	75%	90%
Ricker (PDO)	1	28,000	47,000	84,000	149,000	254,000
MRS	**2**	**16,000**	**27,000**	**48,000**	**85,000**	**141,000**
Ricker (FrD-peak)	3	13,000	22,000	40,000	74,000	128,000
Power-juv (FrD-peak)	3	39,000	60,000	98,000	164,000	270,000

BIRKENHEAD	Rank	Return Forecast 10%	25%	50%	75%	90%
RS4yr	**1**	**12,000**	**27,000**	**63,000**	**148,000**	**319,000**
RS1	2	3,000	7,000	20,000	56,000	143,000
R1C	3	11,000	23,000	53,000	124,000	263,000